Before the

FEDERAL COMMUNICATIONS COMMISSION

Washington, D.C. 20554

In the Matter of	)	
	)	
INQUIRY REGARDING CARRIER	)	**ET Docket No. 03-104**
CURRENT SYSTEMS, INCLUDING	)	
BROADBAND OVER POWER LINE	)	
SYSTEMS	)	

To: The Commission

COMMENTS OF ARRL, THE NATIONAL ASSOCIATION FOR AMATEUR RADIO

ARRL, the National Association for Amateur Radio, also known as the American Radio Relay League, Incorporated (ARRL), by counsel, hereby respectfully submits its comments in response to the *Notice of Inquiry* (the Notice), FCC 03-100, released April 28, 2003, 68 Fed. Reg. 28182; *corrected* 68 Fed. Reg. 32720. The Notice requests information on the current state of Broadband Power Line (BPL) technology. These comments are timely filed. For its comments, ARRL states as follows.

I. Introduction

1. ARRL's interest in this proceeding is related only to the interference potential of BPL to Amateur Radio medium-frequency (MF), high-frequency (HF), and very-high frequency (VHF) communications, and, conversely, the potential for Amateur Radio to interfere with BPL in those same frequency ranges. This matter is of extreme concern to Amateur Radio operators nationally and worldwide, and the extensive record of comments of Amateur Radio operators in this proceeding already reflects that fact. The following comments do not address the utility of BPL as a competitive broadband delivery mechanism. It is presumed for the purposes of these comments that BPL could,

either now, or at some future time, provide a means of broadband delivery that might be somewhat competitive with the plethora of other broadband delivery mechanisms now available. However, ARRL's view, after extensive technical investigation and experience with Part 15 devices generally, with power line interference problems, and with Power Line Carrier (PLC) systems, is that there is severe interference potential from BPL in the bands between 2 and 80 MHz to Amateur Radio stations. This interference potential, as a matter of both law and fact, disqualifies access BPL as a potential future competitive broadband delivery system. ARRL is cognizant of the fact that BPL is permitted under present Part 15 regulations. However, the interference potential from access BPL systems is as yet unrealized, as they are not yet deployed. BPL is a Pandora's Box of unprecedented proportions.[1] The Commission's Part 15 rules should be modified so as to prevent interference to users of the HF and low VHF spectrum *ab initio*, and to prevent consumers' reliance on BPL as an interference-free broadband delivery system.

2. The Amateur Radio Service has small allocations throughout the radio spectrum. By far, the heaviest-used allocations are in the MF band at 1.8 MHz; and in the HF bands at 3.5, 5, 7, 10, 14, 18, 21, 24, and 28 MHz. These bands, though subject to propagation changes due to time of day, time of year, and the time of the eleven-year sunspot cycle, are extremely heavily occupied. The HF amateur bands are used for disaster relief communications and for a series of other public safety communications functions, as well as normal international and domestic avocational and experimental

[1] BPL is qualitatively different as an interference source relative to DSL. BPL is a unique system that uses entire swaths of spectrum; a physical construction that occupies entire communities; a shared wiring system that puts neighbor's BPL system on the same conductors that feed multiple houses from the same power transformers; and the use of widely spaced overhead wiring that by its own geometry forms an effective radiating antenna. Other systems such as DSL may be physically large, but the use of twisted-pair wiring, and the fact that current DSL systems stop at 1.1 MHz creates an entirely different interference potential.

communications. In addition, a very substantial increase in the use of the 50-54 MHz band has occurred in recent years due to the availability of this band to entry-level Technician Class licensees; increases in the number of licensees in that license class; increased availability of commercial transceivers for use on that band; and due to the skywave propagation characteristics at 50-54 MHz, to the point that the band is overcrowded at times. Use of the HF bands is most often from residences, though mobile and portable operation occurs daily as well. Receivers are extremely sensitive, necessitated by the long propagation paths and variable signal strengths due to skywave propagation.

3. The Amateur Service has struggled with terrestrial interference in the HF bands for years. Interference at HF and low VHF is received from a variety of sources. However, a principal source of reported interference is above-ground power lines. ARRL has researched interference from power line radiation for some years, has assisted in interference resolution efforts, and keeps careful logs of interference cases. Power line noise is the single most frequently identified source of HF interference to licensed Amateur Radio operators. During 2002 and 2003 to date, there have been 245 interference complaints reported by ARRL members to ARRL. These are cases in which the radio amateur has not been able to obtain cooperation from the utility company involved. ARRL estimates that this is but a small portion of the number of actual cases of power line interference to Amateur Radio. Most cases are addressed by the Amateur licensee and the utility company, or else the radio amateur merely suffers the interference where cooperation from the utility is not forthcoming. Of the 245 serious power line interference cases reported to ARRL, 108 of these have resulted in letters being sent by

ARRL technical staff to the utility companies. These letters are not sent by ARRL without good cause. They are sent only when informal, cooperative efforts at resolving the interference problems fail. A total of 86 different utility companies have been involved in these written complaints during 2002/03. In a total of 40 cases, ARRL finally had to refer the matter to the Commission's Enforcement Bureau for resolution, due to non-responsiveness on the part of the utility over a long period of time. Mr. Hollingsworth of the Commission's Enforcement Bureau (who has been extremely responsive and helpful) has sent out letters to 23 different utilities about power line interference problems during 2002 and 2003, representing the most egregious cases. It is fair to say that power line interference to Amateur Radio has been a substantial regulatory burden to the Commission. It is a very substantial problem now for the Amateur Service, without the addition of BPL to the mix.

4. Most power line noise complaints involve several calls to the utility from the complainant. Several visits from an RF interference investigator are typically required. Some utilities, even those attempting to be responsive, lack the ability to resolve power line interference problems readily, efficiently and economically. Most often, the case remains open. Some in ARRL's experience have continued for almost ten years. It is with this experience as a predicate that the Amateur Service views with concern and alarm the Commission's consideration of the use of power lines, an excellent radiator of HF and low VHF signals, for broadband delivery to homes on HF and low VHF frequencies.

5. ARRL also has some experience with in-building Power Line Carrier (PLC) systems. These systems and devices, which use a building's electrical wiring to network computers within that building, presumably have other applications as well. An industry

consortium, HomePlug, has a specification for in-building PLCs. ARRL has worked with HomePlug, which ultimately called for notching in product specifications, so as to remove Amateur bands from the operating frequencies of such systems. Even given the notching out of Amateur bands, there is still some interference to Amateur Radio from devices using the HomePlug standard, but not throughout entire neighborhoods. The interference tends to be from adjacent or nearby residences using a HomePlug device, so the number of complaints from these systems today is relatively small. Where they occur, however, the sole remedy appears to be for the user to cease using the device causing the interference.

6. The Commission has recently addressed "control PLC", by which electric utility companies use PLC to send signals on power lines for several miles to control utility equipment. This is done at low frequencies (LF), typically between 10 kHz and 490 kHz. Because the Amateur Service presently has no LF allocations (the lowest frequency Amateur allocation currently is 1.8-2.0 MHz in the medium frequency range) there has not been any interaction between PLCs and the Amateur Service to date. However, the Commission has refused to make any Amateur Radio allocation in the LF range, precisely because of concerns about interference to and from unlicensed PLC systems. In the *Report and Order* in ET Docket No. 02-98, released May 14, 2003, at Paragraph 18, the Commission held, in part, as follows:

> We note the significant potential for interference between the proposed amateur operations and the incumbent PLCs. ARRL concedes that amateur operations and power lines with attached PLCs would have to be separated in order to prevent interference. We find that separation distances on the order of 950 meters would be necessary to protect the PLCs from interference. We also find that this distance, coupled with the larger-than-expected number of PLCs potentially impacted by this

> proposed allocation, increases the likelihood that a PLC-equipped powerline will be close enough to an amateur station to receive interference. We will not jeopardize the reliability of electrical service to the public.

Though the Commission was, in ARRL's view, in serious error in making this finding, it has nonetheless been concluded that, to avoid interference to PLC systems from LF Amateur transmissions (of less than 1 watt EIRP, and assuming extremely inefficient antennas), there would have to be 950 meter separation between the Amateur antenna and the power line. That *Report and Order* also found that PLCs would cause significant interference to Amateur stations at LF. Having made these specific factual conclusions, and given the irrefutable fact that power lines are relatively *inefficient* radiators at LF, the Commission must give serious consideration to the interaction between Amateur transmissions at HF and BPL at HF, where power lines are extremely *efficient* radiators[2] (and where radio amateurs use transmitter power levels up to 1500 watts PEP output and high gain antennas, resulting in EIRP levels as high, in some instances, as 30 kilowatts).[3]

7. The greatest interference potential from BPL to Amateur Radio is with respect to "access BPL" systems, which would provide broadband Internet access to homes and

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[2] Attached hereto as Exhibit A is an ARRL study conducted by its Laboratory entitled "Power Line Antennas from 0.1 to 30 MHz." This study, using a well-known antenna modeling program, EZNEC/4, evaluates the relative efficiencies of power lines as LF and HF radiators. Table 1 of that study shows the calculated gain of a power line antenna at different frequencies. The study concludes that, for a given signal level, the radiated emissions from power lines will increase by tens of dB as the frequency is increased. At HF, power line wiring makes a fair to excellent antenna, similar in gain and pattern to antennas used by licensed radio services. At LF, where the Commission concluded that 950 meter separation between low-power Amateur stations and power lines carrying PLC would be required in order to avoid interaction between the two, the power line model antenna gain is -68dBi. At 10 MHz, for example, that antenna gain increases to +4.6 dB.

[3] The Notice acknowledges the problem, at paragraph 5: "This conducted energy can cause harmful interference to radio communications via two possible paths. First, the RF energy may be carried through the electrical wiring to other devices also connected to the electrical wiring. Second, at frequencies below 30 MHz, where wavelengths exceed 10 meters, long stretches of electrical wiring can act as an antenna,

businesses, using electrical distribution wiring. Overhead wiring is a far better conductor of HF signals than is the electrical wiring within a building. Entire communities will be affected by radiated BPL emissions, and it can easily be seen that interference to Amateur Radio stations will, as a practical matter, not be resolved where the solution is to cease operation of a BPL system in a community. In situations where an Amateur station creates interference to an access BPL system, the level of tolerance of broadband consumers to that interference will be extremely low indeed. So, irrespective of the Part 15 status of BPL, incidents of interaction between the Amateur Service and BPL systems on HF frequencies can be expected to be resolved (in the unlikely event that they could be resolved at all), to the unilateral detriment of Amateur Radio operators.

II. Interference from BPL Emissions

8. ARRL will take the Commission at its word regarding the premise at Paragraph 18 of the Notice, which states as follows:

> In both Access and In-House high-speed BPL technologies, multiple carriers spread signals over a broad range of frequencies that are used by other services that must be protected from interference. In the spectrum below 30 MHz, incumbent authorized operations include…amateur radio terrestrial and satellite…In the spectrum from 30 to 300 MHz, incumbent authorized operations include… amateur radio terrestrial and satellite…Each of these authorized services in the spectrum must be protected from harmful interference.

It is unclear, however, whether the Commission is cognizant of the extreme sensitivity of HF receivers deployed in the Amateur Service, and the extensive disruption of ongoing Amateur Radio communications in the heavily used allocations which would result from

permitting the RF energy to be radiated over the airwaves. Due to the low propagation loss at these frequencies, such radiated energy can cause interference to other services at considerable distances."

deployment of BPL in the HF bands allocated to the Amateur Service. Any such interference can also be presumed to affect other services, in addition to the Amateur Radio Service, which daily conduct terrestrial emergency and safety of life communications in the HF bands.

9. The Notice, beginning at paragraph 20, asks a series of questions regarding interference potential of BPL. These are addressed these in the order in which they are asked in the Notice. The first series of questions addresses use of high-pass filter circuits, and the effect of those on HF signals inside residences from in-house BPL technologies. The problem with the use of high-pass filters as a means of getting a BPL signal past lossy transformers is that they will not only couple the BPL signal onto the MV lines, they will also couple all other RF noise generating device in every building onto the line as well. This will significantly increase the interference potential of devices that otherwise would have been only a local interference source. The MV lines, which may have been relatively quiet previously, will become the distribution source for in-building RF noise. The interference potential from the use of high-pass filters has not, apparently, been conclusively studied, but it will surely impact both the interference potential from a BPL device, and the potential from other conducting emitters in unknown ways. It would be highly premature to permit the use of these filters without knowing more about the interference potential of them using good science.

10. As to the various methods of RF signal injection onto "medium-voltage" (MV) lines, and the effect of different methods on access BPL interference potential, a study of alternatives is attached hereto as Exhibit B.[4] This study was conducted by the

[4] "Methods of Feeding Overhead Medium-Voltage Power Lines with BPL Signals and the Relationship of These Methods to the Radiated Emissions of the Conductors", Exhibit B.

ARRL Laboratory staff. It notes differences in the way that MV distribution lines conduct and radiate signals based on the way RF power is fed to the lines. Using an established antenna-modeling program, EZNEC/4 with the NEC-4 calculation engine, ARRL modeled a simple MV power line and two nearby amateur antennas, conservatively located 30 meters from the lines. Three different models reflected three different ways of feeding the antenna, *to-wit:* differential feed between two phases, at one end; one phase to Earth ground, in the center; and one phase fed differentially similar to the way a dipole is fed, offset on the ungrounded phase.

11. Some conclusions drawn from the study are as follows: Feeding the power line as a dipole is the worst choice from an electromagnetic compatibility perspective. It results in a high powerline antenna gain and greater coupling to the simulated Amateur antennas. At 14 MHz, perhaps the most popular and overcrowded Amateur HF allocation, the gain of the powerline antenna fed in this manner is high enough that the power line has more gain than many antennas intentionally deployed by Amateurs for that band. Feeding the line differentially or from one phase to the ground does result in some improvement in the amount of BPL-signal power delivered to the modem load and in somewhat less energy radiated to the simulated amateur antennas. This does not remove the interference potential, which is governed by Section 15.209 of the Commission's Rules.

12. However, it should be noted that the radiation pattern resulting from the model is complex, and much radiated energy is in upward directions on multiple lobes. There is significant coupling between the modeled power line and the modeled amateur antennas, but it is unclear whether the assumed separation distance represents a worst-

case analysis for this model. The antennas as modeled are located in the radiating near field of the large power line radiator. The near-field effects and the assumed height of the antennas (the first being in the same horizontal plane as the power line; the second 20 meters higher) which results in the amateur antennas being outside the maximum field above the power line, result in this case in somewhat less energy at the modeled point than the path loss calculation would dictate.

13. The Notice next asks whether there is a need to define frequency bands that must be avoided in order to protect the licensed users on the same frequencies used by access BPL systems. It also asks what mitigation techniques can be used by access BPL systems to avoid interference to mobile, public safety, or law enforcement users. ***ARRL has, upon diligent and exhaustive research, concluded that all Amateur medium-frequency (MF, i.e. 1.8-2.0 MHz), all HF, and all VHF allocations must be avoided by any access or in-building BPL system, without exception***. As justification for this position, ARRL has conducted a study, attached hereto as Exhibit C,[5] which calculates (using several different methods) the interference potential of any emitter operating at the Part 15 radiated emissions limits that apply to carrier current devices. Those levels are then used to determine the level of degradation in the ambient noise level at the receiver of several typical HF and VHF amateur station installations. Using the current Section 15.209 radiated emission limits for intentional radiators as the applicable standard, and the permitted levels of 30 μV/m measured at 30 meters for frequencies between 1.705-30 MHz, and 100 μV/m at 3 meters for frequencies between 30 and 88 MHz, the radiated emissions are high enough that signals from BPL emitters will be received by nearby

[5] "Calculated Levels from Broadband Over Power Line Systems and their Impact on Amateur Radio Communications Circuits", Exhibit C.

antennas. The study takes into account various factors, including the noise figure (sensitivity) of the receiver, the gain of the receive antenna, typical natural and man-made ambient noise levels in residential environments, receiver bandwidth, and other factors. It also acknowledges that the Commission's rules do not define specifically how BPL signals must be generated, so encoding and modulation methods may vary significantly. Conservatively, the study assumes that all BPL systems have a peak-to-average power ratio of the emission of 10 dB, close to the ratio of Gaussian noise.

14. The ARRL study utilizes several typical Amateur station configurations taken from standard receiver reference circuits previously provided to the Commission, and which are attached as an appendix to the study. The BPL system assumption is based on maximum or near-maximum permitted radiated field strengths. Since BPL signals appear to Amateur receivers as noise, the increase in noise level is calculated, on a worst-case basis. Also factored in are typical residential ambient noise levels taken from an applicable CCIR Report.[6] However, quieter ambient conditions than those assumed typically exist during winter months in rural areas, by amounts varying from 10 to 20 dB.

15. The conclusions to be drawn from the ARRL Study at Exhibit C, are as follows. As can be seen from Table 3, received signal levels of BPL noise at typical amateur stations are, in worst cases, between 33.7 and 65.4 dB higher than typical ambient noise levels. BPL cannot be deployed using Amateur allocations in the MF, HF and VHF bands without severely high interference potential. To prevent widespread harmful interference from BPL systems, all MF, HF and VHF amateur spectrum must be avoided. The maximum emission limits in Part 15 will result in strong BPL signals being received by nearby Amateur receiver systems, at levels typically as much as 65 dB higher

than the otherwise ambient noise floor. Amateur stations in some especially quiet locations, and stations with antennas that must be located close to electrical wiring will be degraded even more. Even if Amateur spectrum is avoided, the spurious and out-of-band emissions from BPL systems operating on adjacent spectrum must be deeply suppressed. Amateurs whose antennas must be located closer than 30 meters from the radiating power lines will need up to 100 dB of suppression of spurious BPL emissions to operate free of harmful interference. This level of suppression is difficult to obtain.

16. The Notice concludes that the Commission's Part 15 rules have been successful in permitting flexible development of new devices and systems. That is to a large extent correct. However, it would be incorrect to assume that the present Part 15 regulations are sufficient to avoid interference to licensed services, especially at HF. The Part 15 radiated emission limits presume the deployment of point-source radiators with localized interference potential. They were not, in general, designed to deal with multiple-transmitter or radiating distribution systems operating at or near maximum permitted levels over large geographic areas. The rules also assume likely separation between a given Part 15 device and the victim receiver in a licensed service. Those assumptions are each inapplicable in the case of BPL. In many cases, the separation between amateur HF stations and community-wide medium-voltage power lines will be far less than 30 meters, and the systems will be ubiquitous throughout communities. Some access BPL systems now in development use repeaters on the MV lines, repeating the interference potential from one area to many others along the line. Any past "success" with Part 15 type regulation of unlicensed devices or systems is inapplicable to HF or low-VHF deployment of BPL. Most Part 15 devices are not deployed in residences

[6] CCIR Report 322, June, 1995, http://www.nosc.mil/sti/publications/pubs/td/2813/.

adjacent to, and on the same frequencies as, high-power, high-receiver sensitivity Amateur stations used daily. In this case, there is incompatibility between HF BPL and HF Amateur Radio operation, and the former (and spurious emissions from the former) simply cannot be permitted on the same frequencies.

17. The Notice next asks whether access BPL equipment should be considered to be operating in a residential (Class B) rather than commercial (Class A) environment, since it would be installed on medium-voltage lines that supply electricity to a residential neighborhood. The answer to this is patently obvious. Access BPL would operate throughout residential communities, if permitted at all, and would provide a service to residential consumers. It would not and could not be restricted to commercial or industrial environments by its nature, and it therefore cannot be reasonably classified as a Class A system. ARRL has established that BPL is incompatible with HF and VHF Amateur Radio operation from residential areas (and as well in certain mobile environments) and should not be permitted to utilize any spectrum in or proximate to Amateur allocations. In any case, however, BPL must be considered to be, and classified as, a Part 15 system deployed in a residential environment, and subject to stringent radiation standards.

18. The Commission asks what mitigation techniques are used by in-house BPL systems to avoid possible interference with licensed radio services such as Amateur Radio, and whether there is a need to define frequency bands that must be avoided in order to protect the licensed services that use the same frequencies as in-house BPL systems. ARRL has worked with the HomePlug alliance in this respect, and that cooperative effort has resulted in HomePlug's decision to exclude Amateur bands from

its standard. ARRL contends that no in-house BPL system should utilize any Amateur band whatsoever. Amateur receivers are subject to severe interference from in-house BPL operating on Amateur allocations, and in-house BPL systems would be susceptible to interference from the relatively high transmitter and effective radiated power levels from residential Amateur HF station operation. A case study illustrates the problem.[7] There was deployed a model PX-421 wireless modem jack. This was a carrier-current device that operated on 3.53 MHz, in the midst of the Amateur 3.5-4.0 MHz band. It was Verified per the Parts 2 and 15 rules, but when widely deployed, there were widespread reports of harmful interference to Amateur Radio stations. Many units sold were ultimately recalled, but many were found one at a time in the field by radio amateurs and service technicians using directional antennas and spectrum analyzers. The cost of finding larger numbers of such devices would be prohibitive and logistically impossible. Incompatibility between residential deployment of in-house carrier current devices operating on Amateur frequency bands has therefore already been experienced and documented, and has proven extremely difficult to resolve. Clearly, with in-house BPL as with access BPL, the use of Amateur bands must be precluded.[8]

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[7] See, http://www.arrl.org/tis/info/rfieljx.html

[8] The difficulty with exclusion of Amateur bands when authorizing BPL is that Amateur allocations are not static, but dynamic. Recently, in ET Docket 02-the Commission allocated five channels, each 2.8 kHz wide, near 5 MHz for Amateur use. Amateur HF allocations are now under consideration at WRC-03. Any new BPL systems in the HF and VHF bands should not preclude any allocations decisions regarding the Amateur Radio Service. Yet, that is ***exactly*** the position taken by the Commission. The Commission stated in the *Report and Order*, FCC 03-105, released May 14, 2003, at paragraph 17, that:

> "We disagree with the ARRL's and Amateur operators' assertions concerning the consideration we should accord incumbent Part 15 use in these bands in deciding whether to provide an allocation for amateur services. Our decision must be based upon the facts at hand and our evaluation of any potential changes to the spectral environment due to our decision. In evaluating whether new operations should be added to a band, licensed or not, we must consider the potential for interference conflicts between the operations. While unlicensed PLC operations have no protection status, they provide a vital public

19. The Notice asks what probable interference environments and propagation patterns of access BPL and in-house BPL systems exist, and whether specific interference issues, such as increases in the noise floor, should be addressed. It also asks what models are available for predicting radiated emissions from access BPL systems. In addition to the studies heretofore referenced, ARRL has conducted a study of electric and magnetic fields near physically large radiators,[9] which reveals the extremely complex radiated patterns from a simplified powerline model developed under the EZNEC 4.0 program with the NEC-4.1 calculation engine. One conclusion that can be drawn from this study is that it is not practical to try to model a complex installation that consists of overhead power lines, all the other lines that are present nearby such as guy wires, telephone and cable television wiring, and all the wiring in nearby buildings, the configuration of which cannot be determined. Added to that confusion are the unknown losses in the transformers, street lamps, and constantly changing electrical loads in the buildings drawing power from the system. The only reasonable conclusion is that it is not possible to determine the interference potential of BPL wiring with a computer model. Carrier-current devices cannot be measured under controlled laboratory conditions because the power line wiring used to conduct signals is an integral part of the operation; therefore, such systems must be measured *in-situ*. A "typical" installation does not exist, given the

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> service. Therefore, we disagree with amateur comments that we should not consider the impact on unlicensed operations when making spectrum allocation decisions."

From this, it is plain that, should BPL be permitted in the HF or VHF bands, and should any change in the Amateur allocations in that spectrum be permitted at any later date, the Commission might very well conclude, in accordance with this policy, that BPL which provides a competitive broadband access medium for consumers is a vital public service. Therefore, no changes in HF allocations are possible thereafter. This is completely unacceptable to the Amateur Service, and is, *a priori*, bad spectrum policy. The Commission's willingness to predicate allocations decisionmaking on unprotected, at-sufferance unlicensed devices and systems occupying a band, makes it necessary to preclude the introduction of such unlicensed users into the band at all, lest any future Amateur allocation changes be precluded forever after.

wide range of wiring configurations typically found in an electric utility system. The physical configuration of this wiring makes it difficult to determine the point of maximum field strength to demonstrate compliance with any Part 15 rules. This is especially complex where a BPL system might use both medium-voltage lines and in-building wiring to conduct signals between BPL modems and access points. ARRL's study reveals that the Section 15.35(f) test provision, which assumes a 40 dB/decade (square of inverse linear distance extrapolation factor) does not work in the radiating-near-field region of large radiators. When one makes a measurement close to a large radiator, the measurement is close to only a part of the radiating structure, so the field at that point is not affected equally by all parts of the radiator. As one moves to a more distant point, the effect of the more distant parts of the radiator become more significant. The only reliable means to measure a field strength 30 meters from a large radiator is to make multiple measurements along its length in short increments at the specified distance to determine the maximum field, above, below and to the side of the line (These measurement points may not be possible due to access to land where the maximum field occurs). Otherwise, systems may be permitted to exceed the maximum permitted field strength levels that would not be permitted if measurements were made accurately at the specified distances. Additionally, for the same reasons, and because of the differences in the near-field/far-field effect, the Section 15.31 measurement procedure for radiated emissions of carrier current systems at three "typical" or "representative" installations is insufficient and inapplicable to both access and in-building BPL systems

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[9] See, Exhibit D, attached: "Electric and Magnetic Fields near Physically Large Radiators".

20. The Notice asks whether there are test results from field trials of access BPL that may assist in the analysis of harmful interference, or reports of interference from in-house BPL that may assist in analysis of harmful interference. The simple answer is that there are field tests which reveal substantial interference potential to the Amateur Service. There have been several field trials outside of the United States.[10] These studies include interference tests in field trial areas, measuring tens of dB of increase in ambient noise levels, across much of the HF spectrum. In Austria, video recordings were made of some of the field trials.[11] This video is compelling, demonstrating that widespread noise from BPL systems is probable. In the United States, there has been relatively little in-field testing. ARRL has not received significant encouragement from the utilities sponsoring the field tests in the United States, despite efforts to conduct cooperative studies. With respect to one test site in Maryland, after ARRL staff announced to the sponsoring entity their intention to visit the site to conduct some interference measurements at the test site, the site was, without notice, shut down "for maintenance" at the announced date and time of the tests. In any case, it is unclear that the United States test sites represent configurations of access BPL systems that could or would be deployed in the United States, and therefore it is unclear whether any interference testing at those sites would be relevant, much less conclusive. ARRL nevertheless hopes to conduct further interference tests at those sites in the near future, if any cooperation from the sponsoring utilities can be obtained.

21. The Notice asks whether existing Part 15 rules for low speed carrier current systems are adequate to protect authorized users of the spectrum who may be affected by

[10] See, http://www.arrl.org/tis/info/HTML/plc/#Amateur_Interference_Studies.

the new high speed BPL technology, and what changes in those rules are necessary to protect authorized radio services. The attached technical studies and the foregoing argument demonstrate that (1) BPL at HF and low VHF is incompatible with incumbent Amateur operation, and (2) that the existing radiated emission levels permitted by Part 15 are too high, and would permit widespread interference to Amateur HF and VHF stations. BPL should not be permitted in or adjacent to any amateur allocation, and the rules should clarify that any changes in the Table of Allocations domestically which change the Amateur HF or VHF allocations will necessitate retroactive modification of both access and in-building BPL systems to exclude any amateur HF or VHF bands. ARRL does not believe that there are rules which would permit BPL systems to operate in or near Amateur allocations which both adequately protect Amateur Radio stations from interference at HF and VHF, and at the same time "avoid adversely impacting the development and deployment" of BPL. The two systems are fundamentally incompatible.

III. Immunity

22. As far as ARRL has been able to determine, none of the field trials of BPL systems has studied immunity of BPL systems from RF signals of authorized services. The Commission has concluded that LF PLC systems would suffer harmful interference from Amateur stations located 950 meters from a power line carrying PLC, on frequencies where coupling is not particularly efficient. The utility industry argued with respect to PLC interference from Amateur stations that PLCs below 490 kHz would suffer harmful interference from 1 watt EIRP amateur stations. The Commission used that as a premise in refraining from making an allocation for the Amateur Service near 136 kHz. Yet, the same industry, together with BPL manufacturers, is apparently

[11] See, , http://www.arrl.org/tis/info/HTML/plc/#Video.

contending now that at HF and VHF, where the power lines are better antennas than they are at LF, that BPL can co-exist with Amateur stations using more than 10,000 watts EIRP. Both arguments cannot be valid.

23. Typically, if an Amateur station is using 1500 watts and a 3-element parasitic Yagi antenna, the peak field strength 100 feet away in the main antenna lobe will be approximately 30 V/m on HF frequencies. Most industry standards for immunity of consumer grade electronics require that the equipment be immune to fields of approximately 3 V/m. It is unreasonable to expect that BPL equipment will be considerably in excess of that immunity level, given the efficiency of the power line as a receive antenna for signals in the same frequency range. The Amateur Service is most concerned about the BPL immunity issue, because, regardless of the regulatory considerations, consumers of unlicensed RF devices and services have no idea what the relative privileges and immunities of licensed, authorized radio operation are, and a licensed radio amateur will be vilified (or worse) for "causing" interference to internet access provided by BPL. The same utilities that are either unable or unwilling to rectify normal powerline interference problems suffered by radio amateurs cannot be relied on to properly address interference problems to BPL consumers triggered by interference susceptibility of BPL systems, and of which Amateur Radio transmissions are merely the catalyst.

IV. Conclusions

24. The concept of expanded PLC systems at HF and low-band VHF is flawed. There is currently a multitude, and probably sufficient array, of competitive broadband delivery mechanisms. But for the severe interference potential from, especially, access

BPL to licensed Amateur Radio operation, it would be reasonable to add BPL as a competitive means of providing internet access through existing infrastructure. As it is, adding BPL as a broadband delivery system would be akin to reverting to soft coal as a residential heating source. It would work, but at what cost? The Commission has stated as a fundamental principle that incumbent, licensed radio services, including the Amateur Service, must be protected from interference from any deployment of BPL. However, premised on the calculations and technical investigation of the interference potential from these devices, and based on the rather poor track record of utilities generally in dealing with large numbers of interference complaints to date, there is no reason to believe that (1) BPL can coexist with Amateur operation at HF or VHF, or (2) that when the inevitable interference is experienced, the interference problems could or would be rectified.

25. The Commission asks in this Notice of Inquiry, in essence, whether BPL systems should be regulated differently than other Part 15 devices which may operate in the HF bands. The answer is that yes, they must, in order to avoid interference to the sensitive incumbent licensed services in these bands. The present Part 15 regulations were designed to protect against interference from devices that would radiate or conduct signals on a localized basis. The devices for which the Rules were designed typically emit signals only on specific frequencies or bands. BPL systems will occupy all of the HF, low VHF and some MF bands. The relatively high emission limits that work for individual point-source radiators are inapplicable to BPL systems. BPL system radiated levels are complex and difficult to measure due to the length of the powerline acting as an antenna. The increase in noise levels in residential areas over current ambient levels is

reasonably calculated to be as much as 65 dB, due to the efficiency of the powerlines as radiators. There is a fundamental incompatibility between BPL systems in residential areas and Amateur Radio stations. The Commission has found as a matter of fact that separation of 950 meters between Amateur stations operating at 1 Watt EIRP using inefficient antennas would be required at LF, where power lines are relatively inefficient. At HF, where the lines are extremely efficient radiators, and where Amateur stations utilize extremely sensitive receivers, efficient, high-gain antennas, and EIRP levels approaching 10,000 watts, the Commission cannot find that the interaction between Amateur Radio and BPL would be *less* than at LF, where it refused to make an Amateur allocation.

26. The Commission has created a policy whereby it is willing to permit unlicensed devices and systems to occupy bands allocated to licensed radio services. However, it is unwilling, once those unlicensed and unprotected services become deployed on a widespread basis, to create allocations for new or additional licensed services, because interference may result to the unlicensed devices and systems. This is the case with PLC operation at LF. Yet, the HF allocations are dynamic, and change from time to time, either because of international allocations changes or because of domestic changes. At the present time, according to the Commission, the HF spectrum needs of government agencies are undefined. Allowing BPL to occupy the HF spectrum will, if the current Commission policy is applied consistently, preclude any later changes in the HF spectrum which are incompatible with BPL. This is an intolerable situation. ARRL is unwilling to have the Amateur Service gored with the double-edged sword of an

incompatible service that will at once (1) cause widespread interference, and (2) preclude any future changes in the Amateur HF allocations.

27. BPL is, as mentioned above, a Pandora' Box of unprecedented proportions. Once deployed, the consumer's expectations will be such as to preclude termination of the service, and interference problems, both to and from BPL, will inevitably be both widespread and impossible as a practical matter to rectify. The Amateur Service cannot be protected from interference from BPL, and BPL cannot be protected from interference from HF and VHF Amateur stations. The rules must insure that BPL is not permitted to operate in or near any Amateur Radio allocation, and if BPL is permitted at all, any changes in Amateur Radio allocations must immediately trigger retroactive modifications to BPL facilities to delete any use of Amateur frequencies. In addition, spurious emissions from BPL facilities must be substantially attenuated below current Part 15 spurious emission levels.

Therefore, the foregoing considered, ARRL, the National Association for Amateur Radio, respectfully requests that the Commission take no steps to permit access or in-building BPL at HF or VHF at this time.

Respectfully submitted,

ARRL, the National Association For Amateur Radio

225 Main Street
Newington, CT 06111-1494

By:______________________________

Christopher D. Imlay
Its General Counsel

Booth, Freret, Imlay & Tepper, P.C.
14356 Cape May Road

Silver Spring, MD 20904-6011
(301) 384-5525

July 7, 2003

EXHIBIT A

Power Lines as Antennas From 100 kHz to 50 MHz

Author: Ed Hare, ARRL Laboratory Manager[12]
Date: July 7, 2003

1. Electrical transmission lines were designed to conduct 50- or 60-Hz power from point to point. At those frequencies, power lines are excellent transmission lines and little of that 50- or 60-Hz power is radiated. The electric-utility industry also uses those lines at frequencies below 490 kHz to transmit Power Line Carrier signals to control utility equipment. Those lines, however, were not designed to carry radio-frequency energy. As the frequency of carrier-current signals conducted on power lines is raised, the amount of signal radiated from the line increases rapidly.

2. ARRL used a well-known antenna-modeling program, EZNEC PRO[13] 3.0 with the NEC-2 calculation engine[14] to model a simple medium-voltage (MV)[15] neighborhood- distribution power line. The frequency of the signal was varied from 0.1 to 50 MHz. The number of segments per line was increased as necessary as the frequency was increased.

3. Table 1 shows the calculated gain of the power-line antenna model at different frequencies. Figure 1 is a graph of part of the data in Table 1. Figure 2 shows the antenna pattern of the model at various frequencies. The antenna patterns at selected frequencies are shown in Figure 1 and a graph showing the variation in gain vs frequency is shown in Figure 2. Above 1 MHz, the gain continued to increase, although the complexity of the radiated patterns also increased, with significant directivity and peaks and nulls. Examples of this are seen in the patterns of Figures 3 through 5.

4. For a given signal level, the radiated emissions from power lines will increase by tens of dB as the frequency is increased from LF through HF. At HF, power line wiring makes a fair to excellent antenna, similar in gain and pattern to the antennas used by licensed radio services.

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[12] ARRL, Ed Hare, Laboratory Manager, 225 Main St., Newington, CT 06111, Tel: 860-594-0318, Email: w1rfi@arrl.org, Web: http://www.arrl.org/
[13] EZNEC software is available from Roy Lewallen, P.E., PO Box 6658, Beaverton, OR 97007, Tel: 503-646-2885, Email: w7el@eznec.com, Web: http://www.eznec.com
[14] NEC-2 is a freely distributed software available from the Lawrence Livermore National Laboratories, http://www.llnl.gov/.
[15] The FCC NOI refers to the power-line distribution lines as "medium-voltage" lines. The power-line industry usually categorizes lines as distribution equal to or less than 13 kV, sub-transmission less than 69 kV and transmission equal to or greater than 69 kV. In this paper, the term medium-voltage refers to lines that are typically 13 kV or less.

Table 1		
Frequency	Power-line model antenna gain	File
0.1 MHz	-71.0 dBi[16]	DIPR1.EZ
0.2 MHz	-52.1 dBi[3]	DIPR2.EZ
0.3 MHz	-33.9 dBi	DIPR3.EZ
0.5 MHz	-18.3 dBi	DIPR5.EZ
0.8 MHz	-9.9 dBi	DIPR8.EZ
1 MHz	-7.5 dBi	DIP1.EZ
1.8 MHz	-3.4 dBi	DIP1R8.EZ
2 MHz	-2.2 dBi	DIP2.EZ
3.5 MHz	1.6 dBi	DIP3R5.EZ
5.3 MHz	1.2 dBi	DIP5R3.EZ
7 MHz	6.5 dBi	DIP7.EZ
10.1 MHz	7.4 dBi	DIP10R1.EZ
14.0 MHz	7.7 dBi	DIP14.EZ
18.1 MHz	7.6 dBi	DIP18R1.EZ
21.0 MHz	7.8 dBi	DIP21.EZ
24.9 MHz	10.6 dBi	DIP24R9.EZ
28.0 MHz	7.9 dBi	DIP28.EZ
50.0 MHz	9.2 dBi	DIP50.EZ

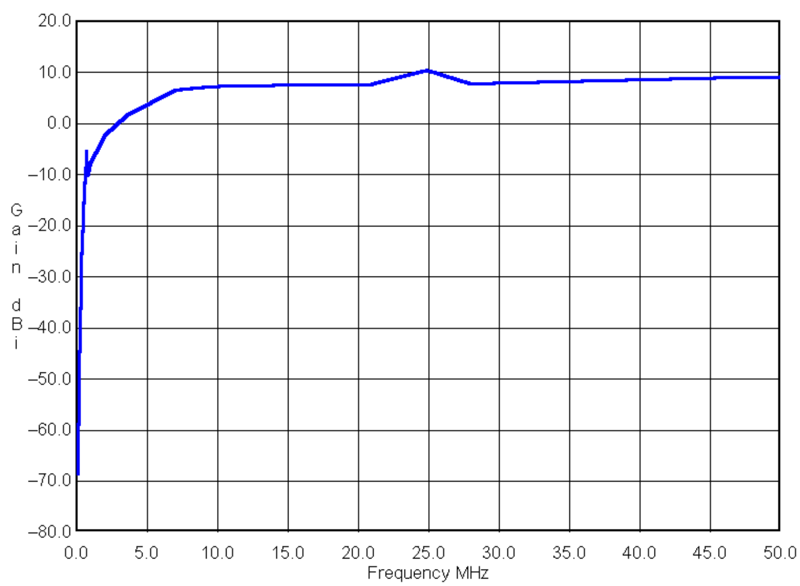

Figure 1: The gain of the power-line as a radiator increases rapidly with frequency. A radiating conductor with relatively low emissions at 0.1 MHz can have emissions tens of dB higher at HF.

[16] At this frequency, the number of segments in the model had to be significantly reduced, stretching the model to the limits. The actual gain is probably somewhat higher than what is indicated in this table.

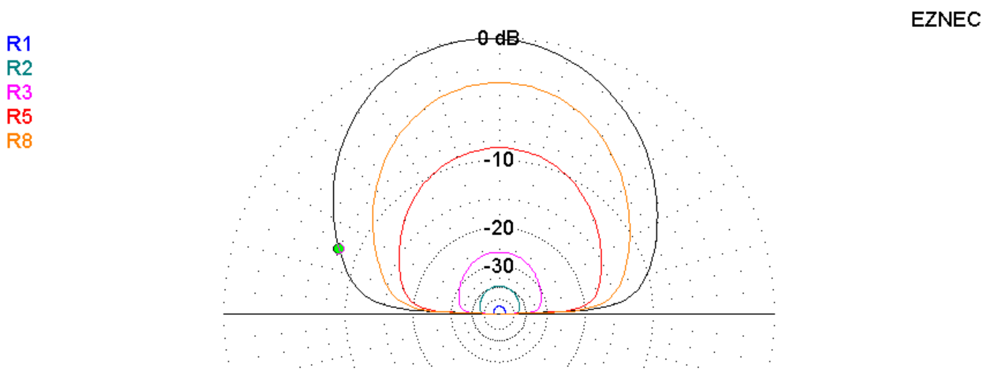

Figure 2:

Trace R1 = 0.1 MHz. Trace R2= 0.2 MHz.
Trace R3 = 0.3 MHz. Trace R5 = 0.5 MHz.
Trace R8 = 0.8 MHz. Outer trace = 1 MHz.
Inner ring = -70 dBi. Outer ring = -7.5 dBi.
(File: pwrline10.ez)

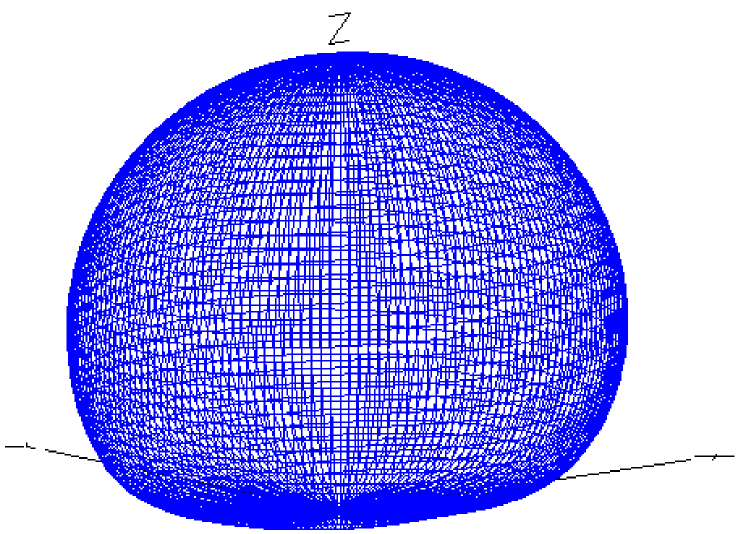

Figure 3:

This 3-D pattern of the power-line model at 1 MHz is close to omnidirectional. The gain on 1 MHz is –7.5 dBi. (File: pwrline10.ez)

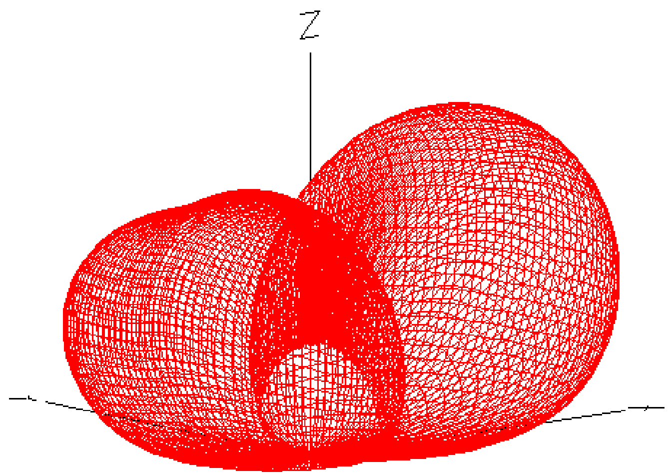

Figure 4:

On 2 MHz, the pattern is already starting to show directivity. The gain in this model is -2.2 dBi. (file: pl2mhz.ez)

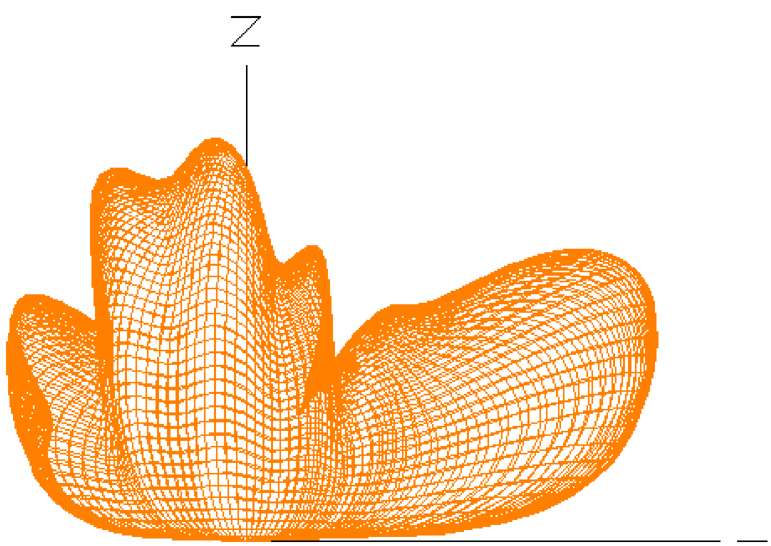

Figure 5:

At 5 MHz, the power-line model is showing considerable gain and directivity. At +1.3 dBi, this is no longer just a transmission line; it has become an effective antenna. Its gain generally increases with frequency. (DIP5.EZ)

Appendix A: Example NEC files used for calculations in this paper/

DIP5.NEC

```
CM Differential, 1 phase, 5 MHz
CE
GW 1,15,120.516,32.9771,10.,79.4021,33.,10.,.00635
GW 2,15,120.516,-22.34,30.,79.4021,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,3.,10.,0.,3.,10.,.00635
GW 6,95,0.,3.,10.,100.,3.,10.,.00635
GW 7,3,100.,0.,10.,100.,3.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,3.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,8,8,50.,0.
LD 4,2,8,8,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,5.
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,201,1,1,-100.,30.,10.,1.,0.,.3048
EN
```

PL2MHZ.NEC

```
CM Differential, 1 phase, 2 MHz
CE
GW 1,1,-100.,0.,10.,-100.,1.,10.,.0127
GW 2,34,-100.,0.,10.,0.,0.,10.,.0127
GW 3,34,0.,0.,10.,100.,0.,10.,.0127
GW 4,4,0.,0.,10.,0.,0.,.01,.0127
GW 5,2,0.,0.,.1,0.,5.,.1,.0127
GW 6,2,0.,0.,.1,-5.,0.,.1,.0127
GW 7,2,0.,0.,.1,0.,-5.,.1,.0127
GW 8,2,0.,0.,.1,5.,0.,.1,.0127
GW 9,67,-100.,1.,10.,100.,1.,10.,.0127
GW 10,1,100.,0.,10.,100.,1.,10.,.0127
GE 1
LD 4,1,1,1,50.,0.
LD 4,10,1,1,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
FR 0,1,0,0,2.
GN 2,0,0,0,13.,.005
EX 0,9,17,0,.9999999,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,1,32,1,-58.,6.,10.,1.,3.,0.
EN
```

PWRLINE10.EZ

```
CM NEC-4 input file <Dipole11.IN>
CE
GW 1,1,-100.,0.,10.,-100.,1.,10.,.0127
GW 2,31,-100.,0.,10.,0.,0.,10.,.0127
GW 3,31,0.,0.,10.,100.,0.,10.,.0127
GW 4,1,0.,0.,10.,0.,0.,.01,.0127
GW 5,1,0.,0.,.1,0.,5.,.1,.0127
GW 6,1,0.,0.,.1,-5.,-4.371E-7,.1,.0127
GW 7,1,0.,0.,.1,5.9624E-8,-5.,.1,.0127
GW 8,1,0.,0.,.1,5.,8.7423E-7,.1,.0127
GW 9,31,-100.,1.,10.,100.,1.,10.,.0127
GW 10,1,100.,0.,10.,100.,1.,10.,.0127
GE 1
LD  4 ,1,1,1,50.,0.
LD  4 ,10,1,1,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
FR 0,1,0,0,1.
GN 2,0,0,0,13.,.005
EX 0,9,8,0,.9999999,0.
RP 0,46,181,1001,0.,0.,2.,2.,0.
NH 0,1,32,1,-58.,6.,10.,1.,3.,0.
EN
```

DIPR1.EZ

```
CM Differential, 1 phase, 0.1 MHz
CE
GW 1,2,-100.,0.,10.,0.,0.,10.,.00635
GW 2,2,0.,0.,10.,100.,0.,10.,.00635
GW 3,2,-100.,1.,10.,0.,1.,10.,.00635
GW 4,2,0.,1.,10.,100.,1.,10.,.00635
GW 5,1,100.,0.,10.,100.,1.,10.,.00635
GW 6,1,-100.,0.,10.,-100.,1.,10.,.00635
GW 7,1,0.,0.,10.,0.,0.,.05,.00635
GW 8,1,0.,0.,.05,0.,5.,.05,.00635
GW 9,1,0.,0.,.05,-5.,0.,.05,.00635
GW 10,1,0.,0.,.05,0.,-5.,.05,.00635
GW 11,1,0.,0.,.05,5.,0.,.05,.00635
GE 1
LD 4,5,1,1,50.,0.
LD 4,6,1,1,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
FR 0,1,0,0,.1
GN 2,0,0,0,13.,.005
EX 0,3,1,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,201,1,41,-200.,0.,0.,2.,0.,1.
EN
```

DIPR2.EZ

```
CM Differential, 1 phase, 0.2 MHz
CE
GW 1,3,-100.,0.,10.,0.,0.,10.,.00635
GW 2,3,0.,0.,10.,100.,0.,10.,.00635
GW 3,3,-100.,1.,10.,0.,1.,10.,.00635
GW 4,3,0.,1.,10.,100.,1.,10.,.00635
GW 5,3,100.,0.,10.,100.,1.,10.,.00635
GW 6,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 7,3,0.,0.,10.,0.,0.,.05,.00635
GW 8,3,0.,0.,.05,0.,5.,.05,.00635
GW 9,3,0.,0.,.05,-5.,0.,.05,.00635
GW 10,3,0.,0.,.05,0.,-5.,.05,.00635
GW 11,3,0.,0.,.05,5.,0.,.05,.00635
GE 1
LD 4,5,2,2,50.,0.
LD 4,6,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
FR 0,1,0,0,.2
GN 2,0,0,0,13.,.005
EX 0,3,1,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,201,1,41,-200.,0.,0.,2.,0.,1.
EN
```

DIPR3.EZ

```
CM Differential, 1 phase, 0.3 MHz
CE
GW 1,4,-100.,0.,10.,0.,0.,10.,.00635
GW 2,4,0.,0.,10.,100.,0.,10.,.00635
GW 3,4,-100.,1.,10.,0.,1.,10.,.00635
GW 4,4,0.,1.,10.,100.,1.,10.,.00635
GW 5,3,100.,0.,10.,100.,1.,10.,.00635
GW 6,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 7,3,0.,0.,10.,0.,0.,.05,.00635
GW 8,3,0.,0.,.05,0.,5.,.05,.00635
GW 9,3,0.,0.,.05,-5.,0.,.05,.00635
GW 10,3,0.,0.,.05,0.,-5.,.05,.00635
GW 11,3,0.,0.,.05,5.,0.,.05,.00635
GE 1
LD 4,5,2,2,50.,0.
LD 4,6,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
FR 0,1,0,0,.3
GN 2,0,0,0,13.,.005
EX 0,3,2,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,201,1,41,-200.,0.,0.,2.,0.,1.
EN
```

DIPR5.EZ

```
CM Differential, 1 phase, 0.5 MHz
CE
GW 1,4,-100.,0.,10.,0.,0.,10.,.00635
GW 2,4,0.,0.,10.,100.,0.,10.,.00635
GW 3,4,-100.,1.,10.,0.,1.,10.,.00635
GW 4,4,0.,1.,10.,100.,1.,10.,.00635
GW 5,3,100.,0.,10.,100.,1.,10.,.00635
GW 6,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 7,3,0.,0.,10.,0.,0.,.05,.00635
GW 8,3,0.,0.,.05,0.,5.,.05,.00635
GW 9,3,0.,0.,.05,-5.,0.,.05,.00635
GW 10,3,0.,0.,.05,0.,-5.,.05,.00635
GW 11,3,0.,0.,.05,5.,0.,.05,.00635
GE 1
LD 4,5,2,2,50.,0.
LD 4,6,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
FR 0,1,0,0,.5
GN 2,0,0,0,13.,.005
EX 0,3,2,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,201,1,41,-200.,0.,0.,2.,0.,1.
EN
```

DIPR8.EZ

```
CM Differential, 1 phase, 0.8 MHz
CE
GW 1,6,-100.,0.,10.,0.,0.,10.,.00635
GW 2,6,0.,0.,10.,100.,0.,10.,.00635
GW 3,6,-100.,1.,10.,0.,1.,10.,.00635
GW 4,6,0.,1.,10.,100.,1.,10.,.00635
GW 5,3,100.,0.,10.,100.,1.,10.,.00635
GW 6,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 7,3,0.,0.,10.,0.,0.,.05,.00635
GW 8,3,0.,0.,.05,0.,5.,.05,.00635
GW 9,3,0.,0.,.05,-5.,0.,.05,.00635
GW 10,3,0.,0.,.05,0.,-5.,.05,.00635
GW 11,3,0.,0.,.05,5.,0.,.05,.00635
GE 1
LD 4,5,2,2,50.,0.
LD 4,6,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
FR 0,1,0,0,.8
GN 2,0,0,0,13.,.005
EX 0,3,2,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,201,1,41,-200.,0.,0.,2.,0.,1.
EN
```

DIP1.EZ

```
CM Differential, 1 phase, 1 MHz
CE
GW 1,7,-100.,0.,10.,0.,0.,10.,.00635
GW 2,7,0.,0.,10.,100.,0.,10.,.00635
GW 3,7,-100.,1.,10.,0.,1.,10.,.00635
GW 4,7,0.,1.,10.,100.,1.,10.,.00635
GW 5,3,100.,0.,10.,100.,1.,10.,.00635
GW 6,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 7,3,0.,0.,10.,0.,0.,.05,.00635
GW 8,3,0.,0.,.05,0.,5.,.05,.00635
GW 9,3,0.,0.,.05,-5.,0.,.05,.00635
GW 10,3,0.,0.,.05,0.,-5.,.05,.00635
GW 11,3,0.,0.,.05,5.,0.,.05,.00635
GE 1
LD 4,5,2,2,50.,0.
LD 4,6,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
FR 0,1,0,0,1.
GN 2,0,0,0,13.,.005
EX 0,3,2,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,201,1,41,-200.,0.,0.,2.,0.,1.
EN
```

```
DIP1R8.EZ
CM Differential, 1 phase, 1.8 MHz
CE
GW 1,11,105.,31.,10.,95.,31.,10.,.00635
GW 2,11,105.,-22.34,30.,95.,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,2,6,6,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,1.8
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,200,1,1,1.,-10.,10.,1.,0.,0.
EN
```

DIP2.EZ

```
CM Differential, 1 phase, 2 MHz
CE
GW 1,11,105.,31.,10.,95.,31.,10.,.00635
GW 2,11,105.,-22.34,30.,95.,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,2,6,6,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,2.
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,200,1,1,1.,-10.,10.,1.,0.,0.
EN
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```
DIP3R5.EZ
CM Differential 1 phase, 3.5 MHz
CE
GW 1,11,120.516,32.9771,10.,79.4021,33.,10.,.00635
GW 2,11,120.516,-22.34,30.,79.4021,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,3.,10.,0.,3.,10.,.00635
GW 6,95,0.,3.,10.,100.,3.,10.,.00635
GW 7,3,100.,0.,10.,100.,3.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,3.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,2,6,6,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,401,1,1,-200.,30.,10.,1.,0.,0.
EN
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DIP5R3.EZ

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CM Differential, 1 phase, 5.3 MHz
CE
GW 1,15,120.516,32.9771,10.,79.4021,33.,10.,.00635
GW 2,15,120.516,-22.34,30.,79.4021,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,3.,10.,0.,3.,10.,.00635
GW 6,95,0.,3.,10.,100.,3.,10.,.00635
GW 7,3,100.,0.,10.,100.,3.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,3.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,8,8,50.,0.
LD 4,2,8,8,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,5.3
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,201,1,1,-100.,30.,10.,1.,0.,.3048
EN
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DIP7.EZ

```
CM Differential, 1 phase, 7 MHz
CE
GW 1,21,120.516,32.9771,10.,79.4021,33.,10.,.00635
GW 2,21,120.516,-22.34,30.,79.4021,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,3.,10.,0.,3.,10.,.00635
GW 6,95,0.,3.,10.,100.,3.,10.,.00635
GW 7,3,100.,0.,10.,100.,3.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,3.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,11,11,50.,0.
LD 4,2,11,11,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,7.
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,201,1,1,-100.,30.,10.,1.,0.,.3048
EN
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DIP10R1.EZ

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CM Differential 1 phase 10.1 MHz
CE
GW 1,29,120.516,32.9771,10.,79.4021,33.,10.,.00635
GW 2,29,120.516,-22.34,30.,79.4021,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,3.,10.,0.,3.,10.,.00635
GW 6,95,0.,3.,10.,100.,3.,10.,.00635
GW 7,3,100.,0.,10.,100.,3.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,3.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,15,15,50.,0.
LD 4,2,15,15,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,10.1
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,201,1,1,-100.,30.,10.,1.,0.,.3048
EN
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DIP14.EZ

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CM Differential, 1 phase, 14 MHz
CE
GW 1,11,105.,31.,10.,95.,31.,10.,.00635
GW 2,11,105.,-22.34,30.,95.,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,2,6,6,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,200,1,1,1.,-10.,10.,1.,0.,0.
EN
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DIP18R1.EZ

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CM Differential 1 phase, 18.1 MHz
CE
GW
1,13,81.2154,23.9779,7.73481,73.4806,23.9779,7.73481,.00491
GW 2,13,81.2154,-17.279,23.2044,73.4806,-
17.279,23.2044,.00491
GW 3,129,-77.348,0.,7.73481,0.,0.,7.73481,.00491
GW 4,129,0.,0.,7.73481,77.348,0.,7.73481,.00491
GW 5,129,-77.348,.77348,7.73481,0.,.77348,7.73481,.00491
GW 6,129,0.,.77348,7.73481,77.348,.77348,7.73481,.00491
GW 7,3,77.348,0.,7.73481,77.348,.77348,7.73481,.00491
GW 8,3,-77.348,0.,7.73481,-77.348,.77348,7.73481,.00491
GW 9,13,0.,0.,7.73481,0.,0.,.03867,.00491
GW 10,13,0.,0.,.03867,0.,7.73481,.03867,.00491
GW 11,13,0.,0.,.03867,-7.7348,0.,.03867,.00491
GW 12,13,0.,0.,.03867,0.,-7.7348,.03867,.00491
GW 13,13,0.,0.,.03867,7.73481,0.,.03867,.00491
GE 1
LD 4,1,7,7,50.,0.
LD 4,2,7,7,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,18.1
GN 2,0,0,0,13.,.005
EX 0,6,65,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,401,1,1,-200.,-10.,10.,1.,0.,.3048
EN
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DIP21.EZ

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CM Differential, 1 phase, 21 MHz
CE
GW
1,13,81.2154,23.9779,7.73481,73.4806,23.9779,7.73481,.00491
GW 2,13,81.2154,-17.279,23.2044,73.4806,-
17.279,23.2044,.00491
GW 3,129,-77.348,0.,7.73481,0.,0.,7.73481,.00491
GW 4,129,0.,0.,7.73481,77.348,0.,7.73481,.00491
GW 5,129,-77.348,.77348,7.73481,0.,.77348,7.73481,.00491
GW 6,129,0.,.77348,7.73481,77.348,.77348,7.73481,.00491
GW 7,3,77.348,0.,7.73481,77.348,.77348,7.73481,.00491
GW 8,3,-77.348,0.,7.73481,-77.348,.77348,7.73481,.00491
GW 9,13,0.,0.,7.73481,0.,0.,.03867,.00491
GW 10,13,0.,0.,.03867,0.,7.73481,.03867,.00491
GW 11,13,0.,0.,.03867,-7.7348,0.,.03867,.00491
GW 12,13,0.,0.,.03867,0.,-7.7348,.03867,.00491
GW 13,13,0.,0.,.03867,7.73481,0.,.03867,.00491
GE 1
LD 4,1,7,7,50.,0.
LD 4,2,7,7,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,21.
GN 2,0,0,0,13.,.005
EX 0,6,65,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,401,1,1,-200.,-10.,10.,1.,0.,.3048
EN
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DIP24R9.EZ

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CM Differential 1 phase 24.9 MHz
CE
GW
1,13,81.2154,23.9779,7.73481,73.4806,23.9779,7.73481,.00491
GW 2,13,81.2154,-17.279,23.2044,73.4806,-
17.279,23.2044,.00491
GW 3,129,-77.348,0.,7.73481,0.,0.,7.73481,.00491
GW 4,129,0.,0.,7.73481,77.348,0.,7.73481,.00491
GW 5,129,-77.348,.77348,7.73481,0.,.77348,7.73481,.00491
GW 6,129,0.,.77348,7.73481,77.348,.77348,7.73481,.00491
GW 7,3,77.348,0.,7.73481,77.348,.77348,7.73481,.00491
GW 8,3,-77.348,0.,7.73481,-77.348,.77348,7.73481,.00491
GW 9,13,0.,0.,7.73481,0.,0.,.03867,.00491
GW 10,13,0.,0.,.03867,0.,7.73481,.03867,.00491
GW 11,13,0.,0.,.03867,-7.7348,0.,.03867,.00491
GW 12,13,0.,0.,.03867,0.,-7.7348,.03867,.00491
GW 13,13,0.,0.,.03867,7.73481,0.,.03867,.00491
GE 1
LD 4,1,7,7,50.,0.
LD 4,2,7,7,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,24.9
GN 2,0,0,0,13.,.005
EX 0,6,65,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,401,1,1,-200.,-10.,10.,1.,0.,.3048
EN
```

DIP28.EZ

```
CM Differential, 1 phase, 28 MHz
CE
GW
1,15,81.2154,23.9779,7.73481,73.4806,23.9779,7.73481,.00491
GW 2,15,81.2154,-17.279,23.2044,73.4806,-
17.279,23.2044,.00491
GW 3,145,-77.348,0.,7.73481,0.,0.,7.73481,.00491
GW 4,145,0.,0.,7.73481,77.348,0.,7.73481,.00491
GW 5,145,-77.348,.77348,7.73481,0.,.77348,7.73481,.00491
GW 6,145,0.,.77348,7.73481,77.348,.77348,7.73481,.00491
GW 7,3,77.348,0.,7.73481,77.348,.77348,7.73481,.00491
GW 8,3,-77.348,0.,7.73481,-77.348,.77348,7.73481,.00491
GW 9,15,0.,0.,7.73481,0.,0.,.03867,.00491
GW 10,15,0.,0.,.03867,0.,7.73481,.03867,.00491
GW 11,15,0.,0.,.03867,-7.7348,0.,.03867,.00491
GW 12,15,0.,0.,.03867,0.,-7.7348,.03867,.00491
GW 13,15,0.,0.,.03867,7.73481,0.,.03867,.00491
GE 1
LD 4,1,8,8,50.,0.
LD 4,2,8,8,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,28.
GN 2,0,0,0,13.,.005
EX 0,6,73,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,401,1,1,-200.,-10.,10.,1.,0.,.3048
EN
```

DIP50.EZ

```
CM Differential 1 phase 50 MHz
CE
GW
1,27,81.2154,23.9779,7.7348,73.4806,23.9779,7.7348,.00491
GW 2,27,81.2154,-17.279,23.2044,73.4806,-
17.279,23.2044,.00491
GW 3,259,-77.348,0.,7.7348,0.,0.,7.7348,.00491
GW 4,259,0.,0.,7.7348,77.348,0.,7.7348,.00491
GW 5,259,-77.348,.77348,7.7348,0.,.77348,7.7348,.00491
GW 6,259,0.,.77348,7.7348,77.348,.77348,7.7348,.00491
GW 7,3,77.348,0.,7.7348,77.348,.77348,7.7348,.00491
GW 8,3,-77.348,0.,7.7348,-77.348,.77348,7.7348,.00491
GW 9,26,0.,0.,7.7348,0.,0.,.03867,.00491
GW 10,26,0.,0.,.03867,0.,7.7348,.03867,.00491
GW 11,26,0.,0.,.03867,-7.7348,0.,.03867,.00491
GW 12,26,0.,0.,.03867,0.,-7.7348,.03867,.00491
GW 13,26,0.,0.,.03867,7.7348,0.,.03867,.00491
GE 1
LD 4,1,14,14,50.,0.
LD 4,2,14,14,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,50.
GN 2,0,0,0,13.,.005
EX 0,6,130,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,401,1,1,-200.,-10.,10.,1.,0.,.3048
EN
```

EXHIBIT B

Methods of Feeding Overhead Electrical Power-Line Distribution Lines With BPL Signals and the Relationship of These Methods to the Radiated Emissions of the Conductors

Author: Ed Hare, ARRL Laboratory Manager[17]

Date: July 7, 2003

1. Introduction

1.1 There are differences in the way that medium-voltage (MV)[18] power-distribution lines conduct and radiate signals based on the way that RF power is fed to the lines. ARRL used a well-known antenna-modeling program, EZNEC PRO[19] 3.0 with the NEC-4.1 calculation engine[20] to model a simple MV power line and two nearby amateur antennas, conservatively located 30 meters from the lines. A pictorial diagram of the model is shown in Figure 1.

1.2 Tables 1 and 2 show the results ARRL obtained by modeling three different ways of feeding the antenna:

- Differential feed between two phases, at one end
- One phase to earth ground, in the center
- One phase fed differentially similar to the way a dipole antenna is fed, offset on the ungrounded phase

2. Description of the Model

2.1 The power-line radiator antenna model was configured with two 12.7 mm copper conductors[21], 200 meters in length. They were placed 10 meters above ground. The ground was modeled with average conductivity and dielectric constant. The two conductors were parallel, spaced 1.0 meter. One of the conductors was grounded to simulate typical imbalance in the line. The ground connection consisted of four 10-meter radials, 5 cm above ground. This is a relatively poor RF ground, to simulate the typical poor RF characteristics of power-line grounds. (This also allows those that don't have access to the NEC-4.1 software to duplicate the results using the more available NEC-2 calculation engine, which cannot handle direct ground connections the same way NEC-4.1 does.)

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[17] ARRL, Ed Hare, Laboratory Manager, 225 Main St., Newington, CT 06111, Tel: 860-594-0318, Email: w1rfi@arrl.org, Web: http://www.arrl.org/

[18] The FCC NOI refers to the power-line distribution lines as "medium-voltage" lines. The power-line industry usually categorizes lines as distribution equal to or less than 13 kV, sub-transmission less than 69 kV and transmission equal to or greater than 69 kV. In this paper, the term medium-voltage refers to lines that are typically 13 kV or less.

[19] EZNEC software is available from Roy Lewellan, P.E., PO Box 6658, Beaverton, OR 97007, Tel: 503-646-2885, Email: w7el@eznec.com, Web: http://www.eznec.com

[20] NEC-4.1 is a licensed software program distributed by the Lawrence Livermore National Laboratories, http://www.llnl.gov/.

[21] EZNEC considers modeled conductor losses when making its calculations.

2.2 Differentially connected loads were placed at each end of the transmission line to properly model the signal losses from various loads present on the line (transformers, BPL modems). This power would not be radiated, so must be accounted for in the model. This also allows the software to calculate the relative efficiency of feeding the system at different points by comparing the power fed to the system and the power that reaches the load, simulating a BPL system modem or repeater. These loads are 50-j0 ohms.

2.3 Two amateur receive antennas are also included in the model. Antenna 1 is a half-wave dipole located 10 meters above ground, at the height of the power line, typical of many amateur tree-mounted antennas. This antenna is 30 meters distant from the line. Antenna 2 is a half-wave dipole located 30 meters above ground, 30 meters diagonally from the line. The height of this antenna is representative of taller amateur tower installations. Each of these antennas has a 50-j0 ohm load in the center and EZNEC is used to calculate the power that reaches each load by radiation.

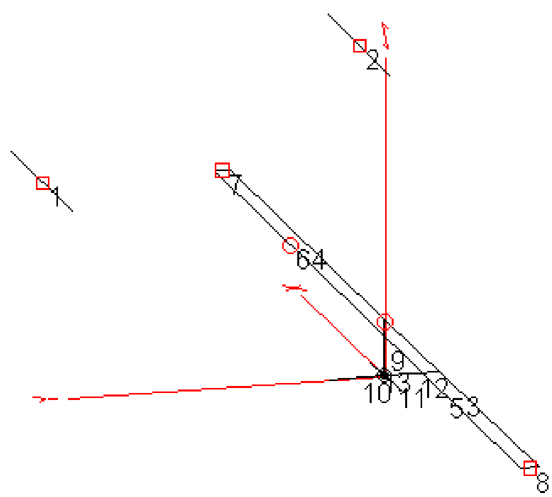

Figure 1: This is a pictorial of the model used by ARRL to calculate differences in the performance of BPL systems fed in different ways.

Point 1 = Amateur half-wave dipole antenna, 10 meters high, 30 meters from line.
Point 2 = Half-wave dipole antenna, 30 meters high, 30 meters diagonally from line.
Point 6 = Single-phase differential "dipole" feed point.
Points 7 and 8 = Two phase differential feed or load, as specified in Tables.
Point 9 = Ground wire, fed where it connects to the phase.
Point 10= Earth ground radials (4).

3. Results

3.1 The results of the modeling are shown in Tables 1 and 2.

Table 1: 14 MHz

Method of feeding the model	Calculated gain of power-line as antenna, including losses	Calculated free-space path loss to 30 meters distance	Modeled loss to antenna 1	Modeled loss to antenna 2	Loss to simulated modem at end of line	EZNEC file[22]
Differential across two phases	+3.7 dBi	24.9 dB	42.8 dB	36.9 dB	8.0 dB	DIFF14.EZ
One phase to earth ground	+3.3 dBi	24.9 dB	38.7 dB	39.4 dB	10.0 dB	GND14.EZ
One phase differential feed[23]	+7.7 dBi	24.9 dB	37.1 dB	40.1 dB	8.6 dB	DIP14.EZ

Table 2: 3.5 MHz

Method of feeding the model	Calculated gain of power-line as antenna, including losses	Calculated free-space path loss to 30 meters distance	Modeled loss to antenna 1	Modeled loss to antenna 2	Loss to simulated modem at end of line	EZNEC file
Differential across two phases	-1.3 dBi	12.9 dB	26.0 dB	20.8 dB	5.8 dB	DIFF3R5.EZ
One phase to earth ground	-2.2 dBi	12.9 dB	24.4 dB	23.2 dB	7.6 dB	GND3R5.EZ
One phase differential Feed	+1.6 dBi	12.9 dB	17.8 dB	16.0 dB	10.8 dB	DIP3R5.EZ

3.2 It is possible to draw several conclusions from these data. Feeding two phases differentially or from one phase to ground results in less energy being radiated than feeding a single phase differentially. From an EMC point of view, feeding a single phase differentially as a dipole is the worst choice, resulting in a higher power-line antenna gain and generally more coupling to the two simulated amateur antennas. On 14 MHz, the gain of the power-line fed this way is high enough that the power line has more gain than many antennas intentionally used by amateurs on that band.

[22] The EZNEC and NEC models used for the calculations in this paper are available for download at http://www.arrl.org/~ehare/rfi/bpl/antenna_models.zip

[23] The FCC NOI describes this feed method as feeding a single phase similar to the way a dipole antenna is fed. In this model, the single phase is fed in this fashion 25% from one end.

3.3 The radiation pattern from this model is quite complex, with many lobes and much energy sent skyward. Antennas 1 and 2 are located near a point with significant coupling between the modeled power line and the modeled amateur antennas, but no effort was made to find the absolute worst case for this model. For example, the modeled antenna radiation pattern shown in Figure 2 demonstrates that maximum-coupling point on 3.5 MHz would be straight up from the power line.

3.4 These antennas are also located in the radiating near field region of the large power-line radiator. The near-field effects and the fact that the simulated amateur antennas are not located in the maximum field above the line results in less energy present at the modeled point than the path-loss calculation shown in the table. Of note, however, on 3.5 MHz, the received signal level in the model is within 3 dB of the path-loss calculation.

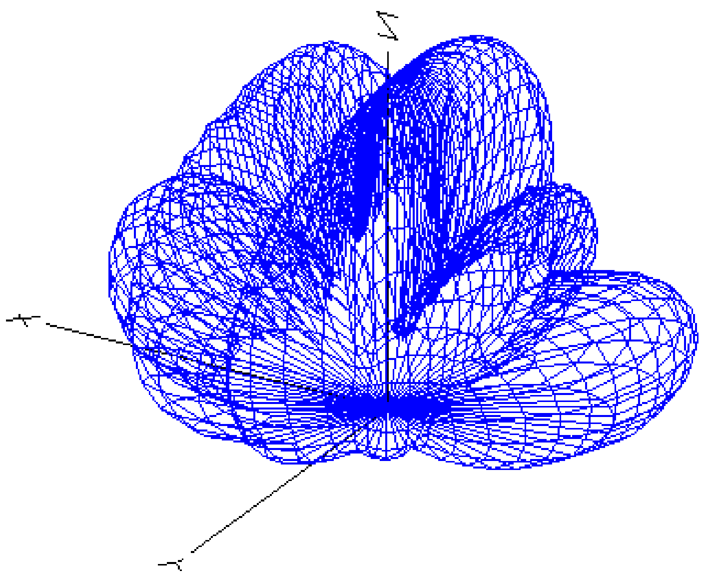

Figure 2: This is the pattern of the 3.5 MHz radiated signal from the power-line model used by ARRL for these calculations. (file: DIP3R5.EZ)

Appendix A: Sample NEC files for the models used for this analysis

DIFF14.NEC

```
CM Differential, 2 phase, 14 MHz
CE
GW 1,11,105.,31.,10.,95.,31.,10.,.00635
GW 2,11,105.,-22.34,30.,95.,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,2,6,6,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,7,2,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,401,1,1,-200.,30.,10.,1.,0.,0.
EN
```

GND14.NEC

```
CM 1 phase to ground, 14 MHz
CE
GW 1,11,105.,31.,10.,95.,31.,10.,.00635
GW 2,11,105.,-22.34,30.,95.,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,2,6,6,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,9,1,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,401,1,1,-200.,30.,10.,1.,0.,0.
EN
```

DIP14.NEC

```
CM Differential, 1 phase, 14 MHz
CE
GW 1,11,105.,31.,10.,95.,31.,10.,.00635
GW 2,11,105.,-22.34,30.,95.,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,2,6,6,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,200,1,1,1.,-10.,10.,1.,0.,0.
EN
```

DIFF3R5.NEC

```
CM Differential, 2 phase, 3.5 MHz
CE
GW 1,11,120.516,32.9771,10.,79.4021,33.,10.,.00635
GW 2,11,120.516,-22.34,30.,79.4021,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,3.,10.,0.,3.,10.,.00635
GW 6,95,0.,3.,10.,100.,3.,10.,.00635
GW 7,3,100.,0.,10.,100.,3.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,3.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,2,6,6,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,7,2,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,401,1,1,-200.,30.,10.,1.,0.,0.
EN
```

GND3R5.NEC

```
CM 1 phase to ground, 3.5 MHz
CE
GW 1,11,120.516,32.9771,10.,79.4021,33.,10.,.00635
GW 2,11,120.516,-22.34,30.,79.4021,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,3.,10.,0.,3.,10.,.00635
GW 6,95,0.,3.,10.,100.,3.,10.,.00635
GW 7,3,100.,0.,10.,100.,3.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,3.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,2,6,6,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,9,1,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,401,1,1,-200.,30.,10.,1.,0.,0.
EN
```

DIP3R5.NEC

```
CM Differential 1 phase, 3.5 MHz
CE
GW 1,11,120.516,32.9771,10.,79.4021,33.,10.,.00635
GW 2,11,120.516,-22.34,30.,79.4021,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,3.,10.,0.,3.,10.,.00635
GW 6,95,0.,3.,10.,100.,3.,10.,.00635
GW 7,3,100.,0.,10.,100.,3.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,3.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,2,6,6,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,401,1,1,-200.,30.,10.,1.,0.,0.
EN
```

EXHIBIT C

Calculated Levels from Broadband Over Power Line Systems and their Impact on Amateur Radio Communications Circuits

Author: Ed Hare, ARRL Laboratory Manager[24]
Date: July 7, 2003

1 **Abstract:** This paper summarizes the results of several different methods of calculating the emissions levels from Broadband Over Power Line systems. The resultant data are then used to determine the calculated level of degradation in the ambient noise level of several types of HF and VHF amateur installations.

2 Calculations Based on the Part 15 Radiated Emissions Limits

2.1 BPL is a carrier-current system and is required to meet the radiated emissions limits for intentional emitters. These limits are:

Section 15.209 Radiated emission limits, general requirements.

(a) Except as provided elsewhere in this Subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

Frequency (MHz)	Field Strength (microvolts/meter)	Measurement Distance (meters)
0.009 - 0.490	2400/F (kHz)	300
0.490 - 1.705	24000/F (kHz)	30
1.705 - 30.0	30	30
30 – 88	100	3
88 – 216	150	3
216 – 960	200	3
Above 960	500	3

2.2 These limits are high enough that signals from unlicensed emitters operating at these limits will be picked up by nearby antennas. The strength and effect of these signals is related to the following factors:

- Strength of the emission
- Frequency of the emission (path loss varies as 20 log[frequency])
- Distance between the source and receiving antennas[25]

[24] ARRL, Ed Hare, Laboratory Manager, 225 Main St., Newington, CT 06111, Tel: 860-594-0318, Email: w1rfi@arrl.org, Web: http://www.arrl.org/

- Gain of the receive antenna
- Noise figure (sensitivity) of the receiver
- Ambient noise level from other sources
- Frequency distribution and nature of the emitted signal
- Receiver bandwidth

2.3 FCC Part 15 rules do not define any specific requirements for the way that BPL signals must be generated, so the encoding and modulation methods can vary significantly. On HF, the quasi-peak-detected radiated emissions from these systems are measured in a 9-kHz bandwidth; on VHF a 100-kHz bandwidth is used. The peak-to-average power ratio of an emission could range from 0 dB for a carrier to tens of dB for some modulation types and systems. Most BPL systems in present use are OFDM (orthogonal frequency-division multiplexing – essentially a multi-carrier system) or DSSS (direct-sequence spread spectrum). The peak-to-average ratio of these systems can vary, depending on how many carriers are present in a given measurement channel. In this paper, it will be conservatively assumed that all BPL systems have a peak-to-average ratio of 10 dB, close to the ratio of gaussian noise.

3. Amateur Stations

3.1 Receive systems used in the Amateur Radio Service have a wide range of function and capabilities. ARRL has selected a few categories within this range and developed hypothetical reference circuits to describe these stations. The reference circuits are included as an appendix to this report. The following are the station configurations that have been selected for this report. This list is by no means complete. A complete copy of ARRL's hypothetical reference-circuit data for the amateur bands between 1.8 and 54 MHz has been provided to the FCC in a separate report.

Table 1:

Station configuration	EIRP	Emission designator[26]	Receiver noise floor	Ambient noise floor[27]
3.5 MHz SSB high-end	43.5 dBW	2K50J3E	-157 dBW	-135 dBW
3.5 MHz SSB typical	38.5 dBW	2K50J3E	-157 dBW	-135 dBW
14 MHz SSB high-end	48.3 dBW	2K50J3E	-157 dBW	-149 dBW
14 MHz SSB typical	43.1 dBW	2K50J3E	-157 dBW	-145 dBW
50 MHz SSB	44.4 dBW	2K50J3E	-168 dBW	-160 dBW

[25] In the far field region, the strength of the electric and magnetic fields varies as $20\log_{10}$(distance). This is only approximately true in the near-field regions.
[26] Receiver bandwidth is the same as the transmit bandwidth defined by the emissions designator.
[27] This includes the effects of typical man-made and atmospheric noise.

typical 50 MHz FM base	21 dBW	15K0F3E	-160 dBW	-152 dBW

4. **Received Signal Levels**

4.1 This analysis assumes that the radiated emissions from most BPL systems will be at or near the permitted FCC limits. The amount of signal an antenna will pick up if it is placed in a specific radiated field would be defined by the following formulas[28] in the far-field region of the two antennas involved:

$$\mathbf{RSL_{dBW} = -107.2 + dBuV/m - 20log_{10}(F_{MHz}) + RcvAntGain_{dBi} - dB_{losses}}$$ [29]

Eq. 1a

$$\mathbf{RSL_{dBm} = -77.2 + dBuV/m - 20log_{10}(F_{MHz}) + RcvAntGain_{dBi} - dB_{losses}}$$

Eq. 1b

4.2 This formula assumes that the RSL is in the same bandwidth as the measurement bandwidth to determine the level in dBuV/m. If the bandwidths are different, then for uncorrelated signals (ie, noiselike) the following correction must be made to the RSL:

$$\mathbf{RSL_{actual} = RSL_{measurement} - 10log\ (measurement\ bandwidth\ /\ receiver\ bandwidth)}$$

Eq. 2

4.3 In-situ, radiated fields include the effects of earth ground and other scattering conductors, so to be conservative, ARRL will use the free-space gain of typical amateur receive antennas for its calculations.[30] Using the formulas above, assuming dB_{losses} = 0 dB, the following data are calculated:

Table 2:

Frequency	Amateur antenna type	Amateura antenna gain	Receive system bandwidth	BPL signal RSL at 30 meters[31]	BPL signal RSL at 10 meters[32]
3.5 MHz[33]	Half-wave dipole	2.14 dBi	2500 Hz	-92 dBW	-82.5 dBW
3.5 MHz	Array	8.0 dBi	2500 Hz	-86.1 dBW	-76.6 dBW
14 MHz	3-element Yagi	8.0 dBi	2500 Hz	-98.1 dBW	-88.6 dBW
14 MHz	Stacked array	13 dBi	2500 Hz	-93.1 dBW	-83.6 dBW

[28] These formulas use the free-space gain of the receive antenna. For low-gain antennas, this will result in a conservative estimate. The field strength at any individual point is determined by the direct signal from the radiator and any scatterers, such as earth ground or other nearby conductors. If the pattern of the antenna has little directivity, it will capture energy from the direct radiation and the scatterers approximately equally, so free-space gain appropriately captures the radiated emissions. For higher-gain antennas with directivity, free-space gain may underestimate the field strength by up to 6 dB.

[29] Losses include the receive antenna feed line, connectors, etc.

[30] This is conservative because antennas located close to ground will lose some of their gain due to impedance mismatch and mutual coupling with the lossy earth.

[31] All RSLs in this table have been corrected for receiver bandwidth relative to the measurement bandwidth in the rules.

[32] The RSL has been corrected to 10 meters distance by using a 20dB/distance decade ratio. This gives a conservative estimate compared to the 40 dB/decade ratio permitted by Part 15 rules.

[33] On 3.5 and 14 MHz, the RSLs are calculated based on a field strength of 30 uV/m at 30 meters distance.

50 MHz[34]	5-element Yagi	9.5 dBi	2500 Hz	-127.7 dBW	-118.2 dBW
50 MHz	¼-wave ground plane	1.6 dBi	15000 Hz	-127.8 dBW	-118.3 dBW

4.4 These RSLs relate to the reference circuits for the amateur stations being analyzed in the following way:

Table 3:

Frequency	Antenna type	Receive system ambient[35]	BPL RSL dB level relative to ambient, 30 meters distance	BPL RSL dB level relative to ambient, 10 meters distance
3.5 MHz	Half-wave dipole	-135 dBW	43 dB	52.5 dB
3.5 MHz	Array	-135 dBW	48.9 dB	58.4 dB
14 MHz	3-element Yagi	-145 dBW	46.9 dB	56.4 dB
14 MHz	Stacked array	-149 dBW	55.9 dB	65.4 dB
50 MHz	5-element Yagi	-160 dBW	32.3 dB	41.8 dB
50 MHz	¼-wave ground plane	-152 dBW	24.2 dB	33.7 dB

4.5 To amateur radio communications, the received BPL signals are noise. The increase in noise level calculated is a conservative calculation of the RSLs that will occur from fields that are at the FCC Part 15 limits for intentional emitters. ARRL has included another paper in its filing, outlining the complex ways that radiated emissions can vary around a large radiating conductor. Near-field effects may also affect the amount of signal picked up on the antenna, in a similar way to how those effects will affect measurements made in the near-field region of the power-line radiator. These effects can be calculated more accurately with antenna-modeling techniques and software.

5. Antenna Modeled Calculations

5.1 These formula-based calculations assume that the coupling between the radiating element and the receive antenna is ideal and that the antenna would be placed at the point of maximum field strength, presumed to be at the FCC Part 15 limit. This normally would be in the main beam of the antenna pattern. This figure, reproduced from another paper ARRL has presented in this filing, "Power Lines as

[34] On 50 MHz, the RSLs are calculated based on a field strength of 100 uV/m at 3 meters distance.

[35] These levels conservatively represent typical residential environs, as described in CCIR Report 322, June 1995, http://www.nosc.mil/sti/publications/pubs/td/2813/. Quiet rural areas ambient levels are 10 to 20 dB lower during the winter months.

Antennas From 0.1 to 30 MHz ," shows the type of radiated pattern that may be typical of medium-voltage (MV)[36] power-distribution lines as radiators.

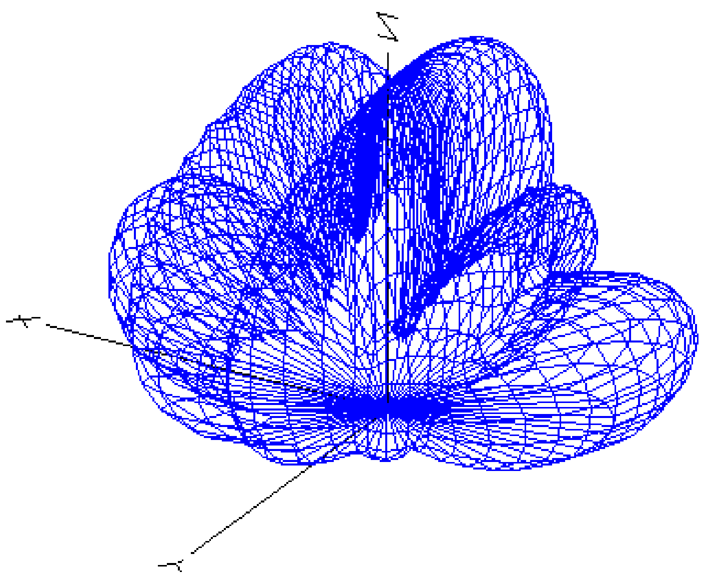

Figure 2: This complex pattern results when a 3.5 MHz signal is applied to the power-line model. On 14 MHz, the same model showed a pattern that was much more complex. (file: DIP3R5.EZ)

5.2 ARRL used the EZNEC[37] model described in a separate paper submitted with this filing, "Electric and Magnetic Fields Near Physically Large Radiators" to establish the correlation between some of the above calculated data and modeled coupling between the power line radiator and nearby half-wave dipole antennas. As in earlier models, the power line was 200 meters long, consisting of two phases, separated by

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[36] The FCC NOI refers to the power-line distribution lines as "medium-voltage" lines. The electric-utility industry usually categorizes lines as distribution equal to or less than 13 kV, sub-transmission less than 69 kV and transmission equal to or greater than 69 kV. In this paper, the term medium-voltage refers to lines that are typically 13 kV or less.

[37] EZNEC software is available from Roy Lewellan, P.E., PO Box 6658, Beaverton, OR 97007, Tel: 503-646-2885, Email: w7el@eznec.com, Web: http://www.eznec.com. This software was being used with the NEC-4.1 calculation engine, a program distributed by the Lawrence Livermore National Laboratories, http://www.llnl.gov.

1 meter. One of the phases was connected to earth ground, using a small radial system, simulating a relatively poor ground. One phase was fed, 25% of the distance from one end. A 50-ohm load was placed at each end of this transmission line model, to simulate the losses and power absorbed by the BPL modems that would be part of this system. A half-wave dipole was placed at various positions in the model and EZNEC was used to determine the amount of received RF energy in a 50-ohm load placed in the center of the dipole. This dipole was always parallel to the power lines and at a distance of 30 meters radially from the line.

5.3 The dipole was modeled at 3 places near the line:

- With its center at the point 30 meters from the line that EZNEC modeled would have the maximum electric field
- With its center opposite the point where one phase was fed, at the height of the modeled power line (10 meters height)
- With its center 30 meters from the center of the power line, at the height of the line (10 meters)

5.4 ARRL obtained the following results:

Table 4:

Frequency	Half-wave dipole center location	30-meter path loss	Loss to modeled half-wave Dipole	EZNEC file
3.5 MHz	At point of maximum electric field above power line X = 85 meters, Y = 0.5 meters, Z = 40 meters	12.9 dB	14.0 dB*	Dip3-1.ez
3.5 MHz	Opposite feed point X = 50 meters, Y = -30 meters, Z = 10 meters	12.9 dB	32.9 dB**	Dip3-2.ez
3.5 MHz	Opposite power-line center X = 0 meters, Y = -30 meters, Z = 10 meters	12.9 dB	30.8 dB	Dip3-3.ez
3.5 MHz	At end nearest feed X = 80 meters, Y = -30 meters, Z = 10 meters	12.9 dB	18.8 dB	Dip3-4.ez
3.5 MHz	At end away from feed X = -80 meters, Y = -30 meters, Z = 10 meters	12.9 dB	27.3 dB	Dip3-5.ez
3.5 MHz	At end away from feed X = -80 meters, Y = -22.4 meters, Z = 30 meters	12.9 dB	16.4 dB	Dip3-6.ez
14 MHz	At point of maximum electric field above power line X = -35 meters, Y = 0.5 meters, Z = 40 meters	24.9 dB	35.7 dB	Dip14-1.ez
14 MHz	Opposite feed point X = 50 meters, Y = -30 meters, Z = 10 meters	24.9 dB	32.61 dB*	Dip14-2.ez
14 MHz	Opposite power-line center X = 0 meters, Y = -30 meters, Z = 10 meters	24.9 dB	44.7 dB**	Dip14-3.ez
14 MHz	At end nearest feed X = 95 meters, Y = -30 meters, Z = 10 meters	24.9 dB	34.5 dB	Dip14-4.ez
14 MHz	At end away from feed X = -95 meters, Y = -30 meters, Z = 10 meters	24.9 dB	35.1 dB	Dip14-5.ez
14 MHz	At end away from feed X = -95 meters, Y = -22.4 meters, Z = 30 meters	24.9 dB	36.7 dB	Dip14-6.ez

* = Worst case of locations modeled per band
** = Best case of locations modeled per band

5.5 ARRL did not perform exhaustive calculations to determine the point of absolute-best coupling between the transmission-line and nearby-amateur-antenna models. The several points ARRL selected on both frequencies modeled indicate that the coupling can and does approach the theoretical coupling derived from the path-loss formula. The path-loss approach to estimate received signal levels is, therefore, a useful tool.

6. Correlation with BPL Power Levels, modeled antenna gain and measured field strength

6.1 ARRL has little data on the characteristics of the present BPL systems. Manufacturers have not published much technical data and the information in the required semiannual reports on the FCC experimental licenses has either not yet been filed, has been filed under a confidentiality request or does not contain much specific information about BPL-system power levels, power-spectral density or losses through the couplers used to connect BPL systems to MV lines.

6.2 As a reasonable starting point, ARRL has presumed that BPL systems that are in current use or development have a device quasi-peak power-spectral density of –80 dBW/Hz. When modulated with high-speed BPL signals, the resultant spectrum can be conservatively considered to be poorly correlated, so the quasi-peak PSD can be presumed reasonably to vary as $10\log_{10}(\text{MeasurementBandwidth}_{\text{Hz}})$. In a 9 kHz bandwidth, this is a quasi-peak signal level of –40.5 dBW. ARRL estimates that the couplers used to connect this signal to the medium-voltage power-distribution lines have a loss of 10 dB. In-building BPL systems typically use a PSD of –86 dBm/Hz[38], with no coupling losses. ARRL has chosen a quasi-peak PSD of –50 dBW / 9 kHz for the following calculations.

6.3 In the far-field region of a radiator, there is a precise relationship between radiated power and field strength. This relationship holds reasonably well for the strongest fields found in the radiating near field of the same radiator.

$$\textbf{Field strength (dBuV/m)} = \textbf{EIRP (dBW)} + 115.7 - 20\log_{10}(\text{distance}_{\text{meters}}) \quad \textbf{Eq. 1}$$

6.4 To obtain a field strength of 29.5 dBuV/m at 30 meters, the emitter would have to have an EIRP of -76.7 dBW. If the BPL-system 9-kHz bandwidth power were –50 dBW, as ARRL has estimated, then the power-line radiator would have to have a gain of –26.7 dBi for the system to meet the FCC Part 15 regulations. ARRL has provided the FCC with a NEC antenna model for a simple power line. This model shows the gains listed in Table 5.

[38] This is the level in the HomePlug specification. This is the most prevalent in-building BPL at this time.

Table 5:

Frequency	Gain (dBi)	File
1.8 MHz	-3.4 dBi	DIP1R8. EZ
3.5 MHz	1.6 dBi	DIP3R5.EZ
5.3 MHz	1.2 dBi	DIP5R3.EZ
7.0 MHz	6.5 dBi	DIP7.EZ
10.1 MHz	7.4 dBi	DIP10R1.EZ
14.0 MHz	7.7 dBi	DIP14.EZ
18.1 MHz	7.6 dBi	DIP18R1.EZ
21.0 MHz	7.8 dBi	DIP21.EZ
24.9 MHz	10.6 dBi	DIP24R9.EZ
28.0 MHz	7.9 dBi	DIP28.EZ
50.0 MHz	9.2 dBi	DIP50.EZ

6.5 In no case was ARRL able to model any load or reasonable change to its model that resulted in a decrease in gain approaching –26.7 dBi. On 14 MHz, varying the value of the loads intended to simulate losses and the attached BPL modems from 10 to 1000 ohms produced changes in gain no more than +- 1 dB from the nominal 7.7 dBi. Once RF is applied to a conductor, its potential as an antenna is determined primarily by its geometry. For physically large wires, loading or losses at the end of that wiring are not a major determining factor in the overall gain of the conductor as an antenna.

6.6 It is difficult to impossible to technically justify that a BPL-systems of –50 dBW / 9 kHz will result in a radiated field strength of +29.5 dBuV/m at 30 meters distance, based on modeling alone. However, in it technical paper, "Electric and Magnetic Fields Near Physically Large Radiators," several additional factors were discussed that could easily explain the differences:

- In real-world BPL installations, it is difficult to obtain access to enough measurement points to ensure that the maximum radiated emission has actually been measured. In all of the peaks, valleys and reflections present near a power-line installation, it is not likely that a few measurements at practical locations will actually find the maximum field.
- On HF, the modeled distribution line had a radiation pattern that resulted in the point of maximum radiation, and the resultant electric and magnetic fields, being at high elevation angles. It is not at all likely that measurements were made at points higher than the overhead distribution lines.
- Making measurements at distances closer than 30 meters and extrapolating at 40 dB/decade can easily result in an underestimation of the actual maximum field at 30 meters distance, by over 20 dB in some cases.
- These factors, taken in combination, easily explain the difference between modeled results and measurements taken in-situ near BPL systems.

Appendix A: Sample NEC files used for the calculations in this paper

DIP3-1.NEC

```
CM Differential, 1 phase, 3.5 MHz
CE
GW 1,11,105.,.5,40.,65.,.5,40.,.00635
GW 2,95,-100.,0.,10.,0.,0.,10.,.00635
GW 3,95,0.,0.,10.,100.,0.,10.,.00635
GW 4,95,-100.,1.,10.,0.,1.,10.,.00635
GW 5,95,0.,1.,10.,100.,1.,10.,.00635
GW 6,3,100.,0.,10.,100.,1.,10.,.00635
GW 7,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 8,11,0.,0.,10.,0.,0.,.05,.00635
GW 9,11,0.,0.,.05,0.,10.,.05,.00635
GW 10,11,0.,0.,.05,-10.,0.,.05,.00635
GW 11,11,0.,0.,.05,0.,-10.,.05,.00635
GW 12,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,6,2,2,50.,0.
LD 4,7,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,5,48,0,1.414214,0.
RP 0,181,1,1000,90.,0.,-1.,0.,0.
NE 0,201,1,1,-100.,30.,10.,1.,0.,.3048
EN
```

DIP3-2.NEC

```
CM Differential, 1 phase, 3.5 MHz
CE
GW 1,11,30.,-30.,10.,70.,-30.,10.,.00635
GW 2,95,-100.,0.,10.,0.,0.,10.,.00635
GW 3,95,0.,0.,10.,100.,0.,10.,.00635
GW 4,95,-100.,1.,10.,0.,1.,10.,.00635
GW 5,95,0.,1.,10.,100.,1.,10.,.00635
GW 6,3,100.,0.,10.,100.,1.,10.,.00635
GW 7,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 8,11,0.,0.,10.,0.,0.,.05,.00635
GW 9,11,0.,0.,.05,0.,10.,.05,.00635
GW 10,11,0.,0.,.05,-10.,0.,.05,.00635
GW 11,11,0.,0.,.05,0.,-10.,.05,.00635
GW 12,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,6,2,2,50.,0.
LD 4,7,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,5,48,0,1.414214,0.
RP 0,181,1,1000,90.,0.,-1.,0.,0.
NE 0,201,1,1,-100.,30.,10.,1.,0.,.3048
EN
```

DIP3-3.NEC

```
CM Differential, 1 phase, 3.5 MHz
CE
GW 1,11,-20.,-30.,10.,20.,-30.,10.,.00635
GW 2,95,-100.,0.,10.,0.,0.,10.,.00635
GW 3,95,0.,0.,10.,100.,0.,10.,.00635
GW 4,95,-100.,1.,10.,0.,1.,10.,.00635
GW 5,95,0.,1.,10.,100.,1.,10.,.00635
GW 6,3,100.,0.,10.,100.,1.,10.,.00635
GW 7,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 8,11,0.,0.,10.,0.,0.,.05,.00635
GW 9,11,0.,0.,.05,0.,10.,.05,.00635
GW 10,11,0.,0.,.05,-10.,0.,.05,.00635
GW 11,11,0.,0.,.05,0.,-10.,.05,.00635
GW 12,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,6,2,2,50.,0.
LD 4,7,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,5,48,0,1.414214,0.
RP 0,181,1,1000,90.,0.,-1.,0.,0.
NE 0,201,1,1,-100.,30.,10.,1.,0.,.3048
EN
```

DIP3-4.NEC

```
CM Differential, 1 phase, 3.5 MHz
CE
GW 1,11,100.,-30.,10.,60.,-30.,10.,.00635
GW 2,95,-100.,0.,10.,0.,0.,10.,.00635
GW 3,95,0.,0.,10.,100.,0.,10.,.00635
GW 4,95,-100.,1.,10.,0.,1.,10.,.00635
GW 5,95,0.,1.,10.,100.,1.,10.,.00635
GW 6,3,100.,0.,10.,100.,1.,10.,.00635
GW 7,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 8,11,0.,0.,10.,0.,0.,.05,.00635
GW 9,11,0.,0.,.05,0.,10.,.05,.00635
GW 10,11,0.,0.,.05,-10.,0.,.05,.00635
GW 11,11,0.,0.,.05,0.,-10.,.05,.00635
GW 12,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,6,2,2,50.,0.
LD 4,7,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,5,48,0,1.414214,0.
RP 0,181,1,1000,90.,0.,-1.,0.,0.
NE 0,201,1,1,-100.,30.,10.,1.,0.,.3048
EN
```

DIP3-5.NEC

```
CM Differential, 1 phase, 3.5 MHz
CE
GW 1,11,-100.,-30.,10.,-60.,-30.,10.,.00635
GW 2,95,-100.,0.,10.,0.,0.,10.,.00635
GW 3,95,0.,0.,10.,100.,0.,10.,.00635
GW 4,95,-100.,1.,10.,0.,1.,10.,.00635
GW 5,95,0.,1.,10.,100.,1.,10.,.00635
GW 6,3,100.,0.,10.,100.,1.,10.,.00635
GW 7,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 8,11,0.,0.,10.,0.,0.,.05,.00635
GW 9,11,0.,0.,.05,0.,10.,.05,.00635
GW 10,11,0.,0.,.05,-10.,0.,.05,.00635
GW 11,11,0.,0.,.05,0.,-10.,.05,.00635
GW 12,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,6,2,2,50.,0.
LD 4,7,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,5,48,0,1.414214,0.
RP 0,181,1,1000,90.,0.,-1.,0.,0.
NE 0,201,1,1,-100.,30.,10.,1.,0.,.3048
EN
```

DIP3-6.NEC

```
CM Differential, 1 phase, 3.5 MHz
CE
GW 1,11,-100.,-22.4,30.,-60.,-22.4,30.,.00635
GW 2,95,-100.,0.,10.,0.,0.,10.,.00635
GW 3,95,0.,0.,10.,100.,0.,10.,.00635
GW 4,95,-100.,1.,10.,0.,1.,10.,.00635
GW 5,95,0.,1.,10.,100.,1.,10.,.00635
GW 6,3,100.,0.,10.,100.,1.,10.,.00635
GW 7,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 8,11,0.,0.,10.,0.,0.,.05,.00635
GW 9,11,0.,0.,.05,0.,10.,.05,.00635
GW 10,11,0.,0.,.05,-10.,0.,.05,.00635
GW 11,11,0.,0.,.05,0.,-10.,.05,.00635
GW 12,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,6,2,2,50.,0.
LD 4,7,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,5,48,0,1.414214,0.
RP 0,181,1,1000,90.,0.,-1.,0.,0.
NE 0,201,1,1,-100.,30.,10.,1.,0.,.3048
EN
```

DIP14-1.NEC

```
CM Differential, 1 phase, 14 MHz
CE
GW 1,39,-30.,.5,40.,-40.,.5,40.,.00635
GW 2,95,-100.,0.,10.,0.,0.,10.,.00635
GW 3,95,0.,0.,10.,100.,0.,10.,.00635
GW 4,95,-100.,1.,10.,0.,1.,10.,.00635
GW 5,95,0.,1.,10.,100.,1.,10.,.00635
GW 6,3,100.,0.,10.,100.,1.,10.,.00635
GW 7,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 8,11,0.,0.,10.,0.,0.,.05,.00635
GW 9,11,0.,0.,.05,0.,10.,.05,.00635
GW 10,11,0.,0.,.05,-10.,0.,.05,.00635
GW 11,11,0.,0.,.05,0.,-10.,.05,.00635
GW 12,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,20,20,50.,0.
LD 4,6,2,2,50.,0.
LD 4,7,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,5,48,0,1.414214,0.
RP 0,181,1,1000,90.,0.,-1.,0.,0.
NE 0,401,1,1,-200.,.5,40.,1.,0.,0.
EN
```

DIP14-2.NEC

```
CM Differential, 1 phase, 14 MHz
CE
GW 1,39,45.,-30.,10.,55.,-30.,10.,.00635
GW 2,95,-100.,0.,10.,0.,0.,10.,.00635
GW 3,95,0.,0.,10.,100.,0.,10.,.00635
GW 4,95,-100.,1.,10.,0.,1.,10.,.00635
GW 5,95,0.,1.,10.,100.,1.,10.,.00635
GW 6,3,100.,0.,10.,100.,1.,10.,.00635
GW 7,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 8,11,0.,0.,10.,0.,0.,.05,.00635
GW 9,11,0.,0.,.05,0.,10.,.05,.00635
GW 10,11,0.,0.,.05,-10.,0.,.05,.00635
GW 11,11,0.,0.,.05,0.,-10.,.05,.00635
GW 12,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,20,20,50.,0.
LD 4,6,2,2,50.,0.
LD 4,7,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,5,48,0,1.414214,0.
RP 0,181,1,1000,90.,0.,-1.,0.,0.
NE 0,401,1,1,-200.,.5,40.,1.,0.,0.
EN
```

DIP14-3.NEC

```
CM Differential, 1 phase, 14 MHz
CE
GW 1,39,-5.,-30.,10.,5.,-30.,10.,.00635
GW 2,95,-100.,0.,10.,0.,0.,10.,.00635
GW 3,95,0.,0.,10.,100.,0.,10.,.00635
GW 4,95,-100.,1.,10.,0.,1.,10.,.00635
GW 5,95,0.,1.,10.,100.,1.,10.,.00635
GW 6,3,100.,0.,10.,100.,1.,10.,.00635
GW 7,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 8,11,0.,0.,10.,0.,0.,.05,.00635
GW 9,11,0.,0.,.05,0.,10.,.05,.00635
GW 10,11,0.,0.,.05,-10.,0.,.05,.00635
GW 11,11,0.,0.,.05,0.,-10.,.05,.00635
GW 12,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,20,20,50.,0.
LD 4,6,2,2,50.,0.
LD 4,7,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,5,48,0,1.414214,0.
RP 0,181,1,1000,90.,0.,-1.,0.,0.
NE 0,401,1,1,-200.,.5,40.,1.,0.,0.
EN
```

DIP14-4.NEC

```
CM Differential, 1 phase, 14 MHz
CE
GW 1,39,100.,-30.,10.,90.,-30.,10.,.00635
GW 2,95,-100.,0.,10.,0.,0.,10.,.00635
GW 3,95,0.,0.,10.,100.,0.,10.,.00635
GW 4,95,-100.,1.,10.,0.,1.,10.,.00635
GW 5,95,0.,1.,10.,100.,1.,10.,.00635
GW 6,3,100.,0.,10.,100.,1.,10.,.00635
GW 7,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 8,11,0.,0.,10.,0.,0.,.05,.00635
GW 9,11,0.,0.,.05,0.,10.,.05,.00635
GW 10,11,0.,0.,.05,-10.,0.,.05,.00635
GW 11,11,0.,0.,.05,0.,-10.,.05,.00635
GW 12,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,20,20,50.,0.
LD 4,6,2,2,50.,0.
LD 4,7,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,5,48,0,1.414214,0.
RP 0,181,1,1000,90.,0.,-1.,0.,0.
NE 0,401,1,1,-200.,.5,40.,1.,0.,0.
EN
```

DIP14-5.NEC

```
CM Differential, 1 phase, 14 MHz
CE
GW 1,39,-100.,-30.,10.,-90.,-30.,10.,.00635
GW 2,95,-100.,0.,10.,0.,0.,10.,.00635
GW 3,95,0.,0.,10.,100.,0.,10.,.00635
GW 4,95,-100.,1.,10.,0.,1.,10.,.00635
GW 5,95,0.,1.,10.,100.,1.,10.,.00635
GW 6,3,100.,0.,10.,100.,1.,10.,.00635
GW 7,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 8,11,0.,0.,10.,0.,0.,.05,.00635
GW 9,11,0.,0.,.05,0.,10.,.05,.00635
GW 10,11,0.,0.,.05,-10.,0.,.05,.00635
GW 11,11,0.,0.,.05,0.,-10.,.05,.00635
GW 12,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,20,20,50.,0.
LD 4,6,2,2,50.,0.
LD 4,7,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,5,48,0,1.414214,0.
RP 0,181,1,1000,90.,0.,-1.,0.,0.
NE 0,401,1,1,-200.,.5,40.,1.,0.,0.
EN
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DIP14-6.NEC

```
CM Differential, 1 phase, 14 MHz
CE
GW 1,39,-100.,-22.4,30.,-90.,-22.4,30.,.00635
GW 2,95,-100.,0.,10.,0.,0.,10.,.00635
GW 3,95,0.,0.,10.,100.,0.,10.,.00635
GW 4,95,-100.,1.,10.,0.,1.,10.,.00635
GW 5,95,0.,1.,10.,100.,1.,10.,.00635
GW 6,3,100.,0.,10.,100.,1.,10.,.00635
GW 7,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 8,11,0.,0.,10.,0.,0.,.05,.00635
GW 9,11,0.,0.,.05,0.,10.,.05,.00635
GW 10,11,0.,0.,.05,-10.,0.,.05,.00635
GW 11,11,0.,0.,.05,0.,-10.,.05,.00635
GW 12,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,20,20,50.,0.
LD 4,6,2,2,50.,0.
LD 4,7,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,5,48,0,1.414214,0.
RP 0,181,1,1000,90.,0.,-1.,0.,0.
NE 0,401,1,1,-200.,.5,40.,1.,0.,0.
EN
```

DIP1R8.NEC

```
CM Differential, 1 phase, 1.8 MHz
CE
GW 1,11,105.,31.,10.,95.,31.,10.,.00635
GW 2,11,105.,-22.34,30.,95.,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,2,6,6,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,1.8
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,200,1,1,1.,-10.,10.,1.,0.,0.
EN
```

DIP3R5.NEC

```
CM Differential 1 phase, 3.5 MHz
CE
GW 1,11,120.516,32.9771,10.,79.4021,33.,10.,.00635
GW 2,11,120.516,-22.34,30.,79.4021,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,3.,10.,0.,3.,10.,.00635
GW 6,95,0.,3.,10.,100.,3.,10.,.00635
GW 7,3,100.,0.,10.,100.,3.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,3.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,2,6,6,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,401,1,1,-200.,30.,10.,1.,0.,0.
EN
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DIP5R3.NEC

```
CM Differential, 1 phase, 5.3 MHz
CE
GW 1,15,120.516,32.9771,10.,79.4021,33.,10.,.00635
GW 2,15,120.516,-22.34,30.,79.4021,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,3.,10.,0.,3.,10.,.00635
GW 6,95,0.,3.,10.,100.,3.,10.,.00635
GW 7,3,100.,0.,10.,100.,3.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,3.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,8,8,50.,0.
LD 4,2,8,8,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,5.3
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,201,1,1,-100.,30.,10.,1.,0.,.3048
EN
```

DIP7.NEC

```
CM Differential, 1 phase, 7 MHz
CE
GW 1,21,120.516,32.9771,10.,79.4021,33.,10.,.00635
GW 2,21,120.516,-22.34,30.,79.4021,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,3.,10.,0.,3.,10.,.00635
GW 6,95,0.,3.,10.,100.,3.,10.,.00635
GW 7,3,100.,0.,10.,100.,3.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,3.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,11,11,50.,0.
LD 4,2,11,11,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,7.
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,201,1,1,-100.,30.,10.,1.,0.,.3048
EN
```

DIP10R1.NEC

```
CM Differential 1 phase 10.1 MHz
CE
GW 1,29,120.516,32.9771,10.,79.4021,33.,10.,.00635
GW 2,29,120.516,-22.34,30.,79.4021,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,3.,10.,0.,3.,10.,.00635
GW 6,95,0.,3.,10.,100.,3.,10.,.00635
GW 7,3,100.,0.,10.,100.,3.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,3.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,15,15,50.,0.
LD 4,2,15,15,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,10.1
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,201,1,1,-100.,30.,10.,1.,0.,.3048
EN
```

DIP14.NEC

```
CM Differential, 1 phase, 14 MHz
CE
GW 1,11,105.,31.,10.,95.,31.,10.,.00635
GW 2,11,105.,-22.34,30.,95.,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,2,6,6,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,200,1,1,1.,-10.,10.,1.,0.,0.
EN
```

DIP18R1.NEC

```
CM Differential 1 phase, 18.1 MHz
CE
GW
1,13,81.2154,23.9779,7.73481,73.4806,23.9779,7.73481,.00491
GW 2,13,81.2154,-17.279,23.2044,73.4806,-
17.279,23.2044,.00491
GW 3,129,-77.348,0.,7.73481,0.,0.,7.73481,.00491
GW 4,129,0.,0.,7.73481,77.348,0.,7.73481,.00491
GW 5,129,-77.348,.77348,7.73481,0.,.77348,7.73481,.00491
GW 6,129,0.,.77348,7.73481,77.348,.77348,7.73481,.00491
GW 7,3,77.348,0.,7.73481,77.348,.77348,7.73481,.00491
GW 8,3,-77.348,0.,7.73481,-77.348,.77348,7.73481,.00491
GW 9,13,0.,0.,7.73481,0.,0.,.03867,.00491
GW 10,13,0.,0.,.03867,0.,7.73481,.03867,.00491
GW 11,13,0.,0.,.03867,-7.7348,0.,.03867,.00491
GW 12,13,0.,0.,.03867,0.,-7.7348,.03867,.00491
GW 13,13,0.,0.,.03867,7.73481,0.,.03867,.00491
GE 1
LD 4,1,7,7,50.,0.
LD 4,2,7,7,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,18.1
GN 2,0,0,0,13.,.005
EX 0,6,65,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,401,1,1,-200.,-10.,10.,1.,0.,.3048
EN
```

DIP21.NEC

```
CM Differential, 1 phase, 21 MHz
CE
GW
1,13,81.2154,23.9779,7.73481,73.4806,23.9779,7.73481,.00491
GW 2,13,81.2154,-17.279,23.2044,73.4806,-
17.279,23.2044,.00491
GW 3,129,-77.348,0.,7.73481,0.,0.,7.73481,.00491
GW 4,129,0.,0.,7.73481,77.348,0.,7.73481,.00491
GW 5,129,-77.348,.77348,7.73481,0.,.77348,7.73481,.00491
GW 6,129,0.,.77348,7.73481,77.348,.77348,7.73481,.00491
GW 7,3,77.348,0.,7.73481,77.348,.77348,7.73481,.00491
GW 8,3,-77.348,0.,7.73481,-77.348,.77348,7.73481,.00491
GW 9,13,0.,0.,7.73481,0.,0.,.03867,.00491
GW 10,13,0.,0.,.03867,0.,7.73481,.03867,.00491
GW 11,13,0.,0.,.03867,-7.7348,0.,.03867,.00491
GW 12,13,0.,0.,.03867,0.,-7.7348,.03867,.00491
GW 13,13,0.,0.,.03867,7.73481,0.,.03867,.00491
GE 1
LD 4,1,7,7,50.,0.
LD 4,2,7,7,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,21.
GN 2,0,0,0,13.,.005
EX 0,6,65,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,401,1,1,-200.,-10.,10.,1.,0.,.3048
EN
```

DIP24R9.NEC

```
CM Differential 1 phase 24.9 MHz
CE
GW
1,13,81.2154,23.9779,7.73481,73.4806,23.9779,7.73481,.00491
GW 2,13,81.2154,-17.279,23.2044,73.4806,-
17.279,23.2044,.00491
GW 3,129,-77.348,0.,7.73481,0.,0.,7.73481,.00491
GW 4,129,0.,0.,7.73481,77.348,0.,7.73481,.00491
GW 5,129,-77.348,.77348,7.73481,0.,.77348,7.73481,.00491
GW 6,129,0.,.77348,7.73481,77.348,.77348,7.73481,.00491
GW 7,3,77.348,0.,7.73481,77.348,.77348,7.73481,.00491
GW 8,3,-77.348,0.,7.73481,-77.348,.77348,7.73481,.00491
GW 9,13,0.,0.,7.73481,0.,0.,.03867,.00491
GW 10,13,0.,0.,.03867,0.,7.73481,.03867,.00491
GW 11,13,0.,0.,.03867,-7.7348,0.,.03867,.00491
GW 12,13,0.,0.,.03867,0.,-7.7348,.03867,.00491
GW 13,13,0.,0.,.03867,7.73481,0.,.03867,.00491
GE 1
LD 4,1,7,7,50.,0.
LD 4,2,7,7,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,24.9
GN 2,0,0,0,13.,.005
EX 0,6,65,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,401,1,1,-200.,-10.,10.,1.,0.,.3048
EN
```

DIP28.NEC

```
CM Differential, 1 phase, 28 MHz
CE
GW
1,15,81.2154,23.9779,7.73481,73.4806,23.9779,7.73481,.00491
GW 2,15,81.2154,-17.279,23.2044,73.4806,-
17.279,23.2044,.00491
GW 3,145,-77.348,0.,7.73481,0.,0.,7.73481,.00491
GW 4,145,0.,0.,7.73481,77.348,0.,7.73481,.00491
GW 5,145,-77.348,.77348,7.73481,0.,.77348,7.73481,.00491
GW 6,145,0.,.77348,7.73481,77.348,.77348,7.73481,.00491
GW 7,3,77.348,0.,7.73481,77.348,.77348,7.73481,.00491
GW 8,3,-77.348,0.,7.73481,-77.348,.77348,7.73481,.00491
GW 9,15,0.,0.,7.73481,0.,0.,.03867,.00491
GW 10,15,0.,0.,.03867,0.,7.73481,.03867,.00491
GW 11,15,0.,0.,.03867,-7.7348,0.,.03867,.00491
GW 12,15,0.,0.,.03867,0.,-7.7348,.03867,.00491
GW 13,15,0.,0.,.03867,7.73481,0.,.03867,.00491
GE 1
LD 4,1,8,8,50.,0.
LD 4,2,8,8,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,28.
GN 2,0,0,0,13.,.005
EX 0,6,73,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,401,1,1,-200.,-10.,10.,1.,0.,.3048
EN
```

DIP50.NEC

```
CM Differential 1 phase 50 MHz
CE
GW
1,27,81.2154,23.9779,7.7348,73.4806,23.9779,7.7348,.00491
GW 2,27,81.2154,-17.279,23.2044,73.4806,-
17.279,23.2044,.00491
GW 3,259,-77.348,0.,7.7348,0.,0.,7.7348,.00491
GW 4,259,0.,0.,7.7348,77.348,0.,7.7348,.00491
GW 5,259,-77.348,.77348,7.7348,0.,.77348,7.7348,.00491
GW 6,259,0.,.77348,7.7348,77.348,.77348,7.7348,.00491
GW 7,3,77.348,0.,7.7348,77.348,.77348,7.7348,.00491
GW 8,3,-77.348,0.,7.7348,-77.348,.77348,7.7348,.00491
GW 9,26,0.,0.,7.7348,0.,0.,.03867,.00491
GW 10,26,0.,0.,.03867,0.,7.7348,.03867,.00491
GW 11,26,0.,0.,.03867,-7.7348,0.,.03867,.00491
GW 12,26,0.,0.,.03867,0.,-7.7348,.03867,.00491
GW 13,26,0.,0.,.03867,7.7348,0.,.03867,.00491
GE 1
LD 4,1,14,14,50.,0.
LD 4,2,14,14,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,50.
GN 2,0,0,0,13.,.005
EX 0,6,130,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,401,1,1,-200.,-10.,10.,1.,0.,.3048
EN
```

EXHIBIT D

Electric and Magnetic Fields Near Physically Large Radiators

Author: Ed Hare, ARRL Laboratory Manager[39]
Date: July 7, 2003

1. Overview

1.1 Making measurements of electric and magnetic field strength requires specialized equipment and skills. Most measurements are made by trained personnel in carefully controlled laboratory or open-area-test-site conditions. Even under these ideal conditions, uncertainty of 3-4 dB is considered to be reasonably good testing.

1.2 Carrier-current devices cannot be measured under controlled laboratory conditions because the power-line wiring they use to conduct signals is an integral part of their operation. They must be measured in-situ.

1.3 Part 15 rules require that carrier-current devices be verified by the manufacturer for compliance with the limits for intentional emitters in three "typical" locations. Even under the best of circumstances, it is difficult to determine what is "typical" for a device that can be used with the wide range of the electrical-distribution wiring types and configurations typically found in an electric-utility system. BPL systems can be deployed using residential or business wiring as conductors in a single building, or using overhead distribution medium-voltage (MV)[40] lines that may be miles long. The physical configuration of this wiring can make it very difficult to determine the point of maximum field strength to demonstrate compliance with Part 15. In many cases, it is not possible to obtain access to most of the area surrounding a BPL installation, so even the most-careful work may not measure the actual maximum emission. Some access BPL systems use *both* the MV lines and building wiring to conduct signals between BPL modems and access points, adding the uncertainties of the radiation building wiring to the already-complicated measurement site.

2. Radiated Patterns

2.1 The following two figures show the far-field radiated energy pattern from a simplified power-line model ARRL developed to run under EZNEC 4.0 with the NEC-4.1 calculation engine[41,42]. This model was described in another paper[43]

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[39] ARRL, Ed Hare, Laboratory Manager, 225 Main St., Newington, CT 06111, Tel: 860-594-0318, Email: w1rfi@arrl.org, Web: http://www.arrl.org/

[40] The FCC NOI refers to the power-line distribution lines as "medium-voltage" lines. The power-line industry usually categorizes lines as distribution equal to or less than 13 kV, sub-transmission less than 69 kV and transmission equal to or greater than 69 kV. In this paper, the term medium-voltage refers to lines that are typically 13 kV or less.

[41] EZNEC software is available from Roy Lewallen, P.E., PO Box 6658, Beaverton, OR 97007, Tel: 503-646-2885, Email: w7el@eznec.com, Web: http://www.eznec.com.

[42] NEC-4 is a licensed software distributed by the Lawrence Livermore National Laboratories, http://www.llnl.gov/.

provided to the Commission by ARRL, "Methods of Feeding Overhead Electrical Power-Line Distribution Lines With BPL Signals and the Relationship of These Methods to the Radiated Emissions of the Conductors." A drawing of the model is reproduced in Figure 1.

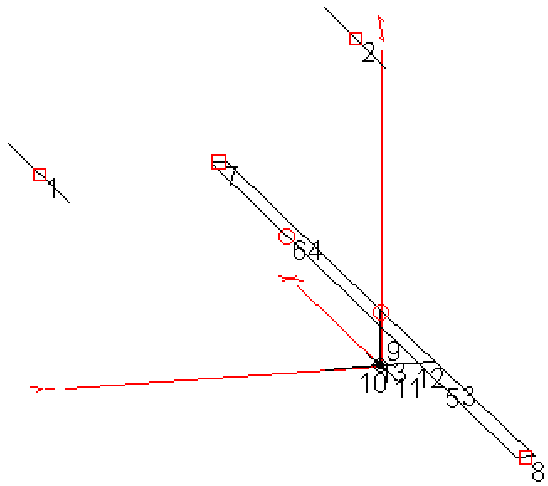

Figure 1: This is a pictorial of the model[44] used by ARRL to calculate differences in the performance of BPL systems fed in different ways.

Point 1 = Amateur half-wave dipole antenna, 10 meters high, 30 meters from line.
Point 2 = Half-wave dipole antenna, 30 meters high, 30 meters diagonally from line.
Point 6 = Single-phase differential "dipole" feed point.
Points 7 and 8 = Two phase differential feed or load, as specified in Tables.
Point 9 = Ground wire, fed where it connects to the phase.
Point 10= Earth ground radials (4).

2.2 The far-field radiated patterns from this model are shown in Figures 2 and 3. Figure 2 is modeled on 3.5 MHz and Figure 3 is modeled on 14 MHz. The near-field

[43] "Methods of Feeding Overhead Medium-Voltage Power Lines With BPL Signals and the Relationship of These Methods to the Radiated Emissions of the Conductors," Author: Ed Hare, ARRL Laboratory Manager.

[44] The power-line model was 10 meters above ground with average conductivity and dielectric constant. The line consisted of two copper conductors, 0.12.5 mm diameter, 200 meters long. One of the conductors was grounded to simulate typical imbalance in the line. Because access BPL systems that are in development or field trial use inductive coupling to feed one line like a dipole, this is the model ARRL used for the plots in this reports. To allow this model to work on various versions of NEC, the ground connection consisted of four 10-meter radials, 5 cm above ground. This also reasonably simulates the relatively poor RF characteristics of power-line grounds. Differentially connected 50-j0 ohms loads were placed at each end of the transmission line. Two amateur antennas are also placed in the model. Antenna 1 is a half-wave dipole located 10 meters above ground, at the height of the power line, typical of many amateur tree-mounted antennas. Antenna 2 is a half-wave dipole located 30 meters above ground, 30 meters diagonally from the line. The height of this antenna is typical of many amateur tower installations. These antennas each have a 50-j0 ohm load in the center.

pattern at 30 meters distance will be closely related to the pattern in the far field, generally with more peaks and valleys in the field strength. These peaks and valleys are shown graphically in Figures 5 and 6.

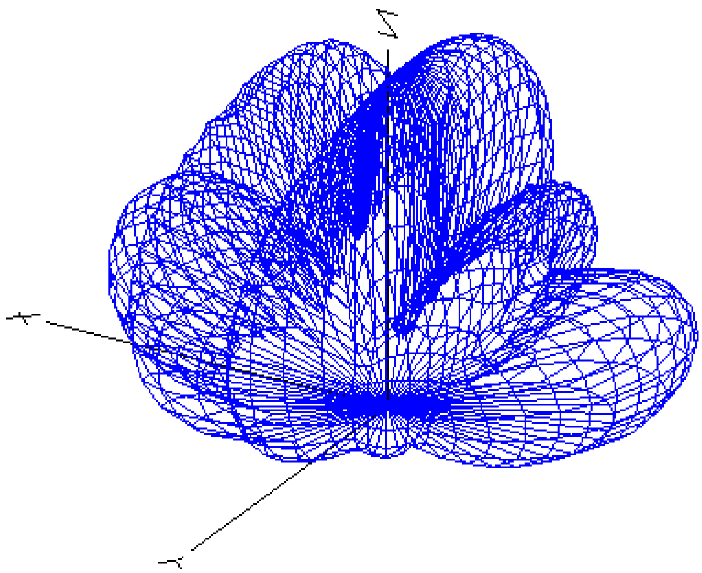

Figure 2: This complex pattern results when a 3.5 MHz signal is applied to the power-line model. (file:dip3r5.ez[45])

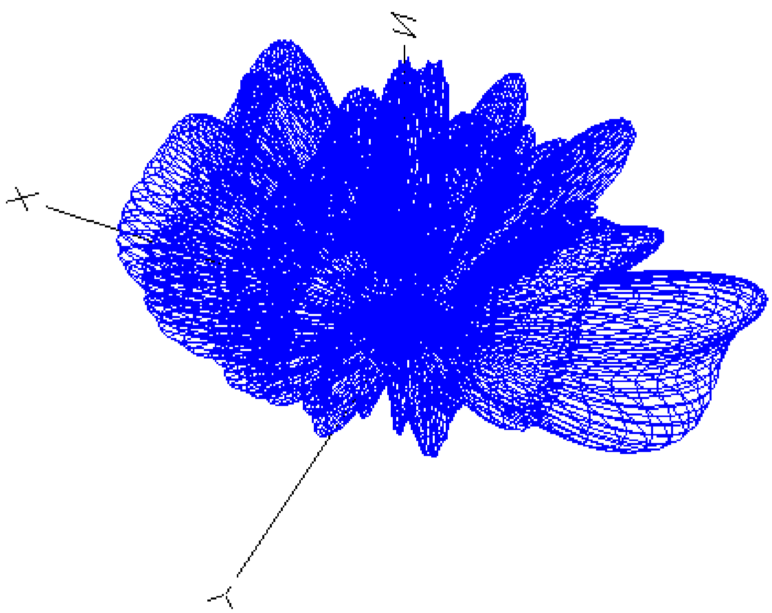

Figure 3: The pattern on 14 MHz from the same line is even more complex. (file:dip14.ez)

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[45] The EZNEC and NEC models used for the calculations in this paper are available for download at http://www.arrl.org/~ehare/rfi/bpl/antenna_models.zip

2.3 Even with this simple model of a single line over ground, it would be difficult to impossible to find the point of maximum field strength near this model. In the case of overhead power lines, in many cases, a test engineer wouldn't have access to all points near the wiring of an entire BPL installation, due to parking or private-property-access restrictions. If several points near this model were selected on the basis of their being accessible, it is not likely that they would be at the peaks, resulting in the actual emissions being higher than tested.

2.4 In most cases, for radiators at the height of typical distribution lines, especially on MF and HF, the point at which the maximum field strength will be found is higher than the radiator. To actually measure this energy would require placing a test antenna higher than the line, at a vertical or diagonal distance of 30 meters. For compliance, however, it is necessary that this point of maximum radiation be determined. Many antennas, such as amateur towers greater than 10 meters in height; antennas with stations operating from airplanes or other antennas located on terrain higher than the power lines will be at points higher than the lines. Although individual BPL modems will not generally propagate at levels strong enough to be heard by skywave, the aggregate of many such devices in a major metropolitan area can have enough total power to do so. Carefully controlling the radiated field strength upwards is important.

3. A More Complicated Model With Additional Distribution Legs

3.1 Real-world power lines are more complicated than the simple model ARRL used, so the variations and deviations from the above patterns will be significant. In most cases, the pattern will be even more complex.

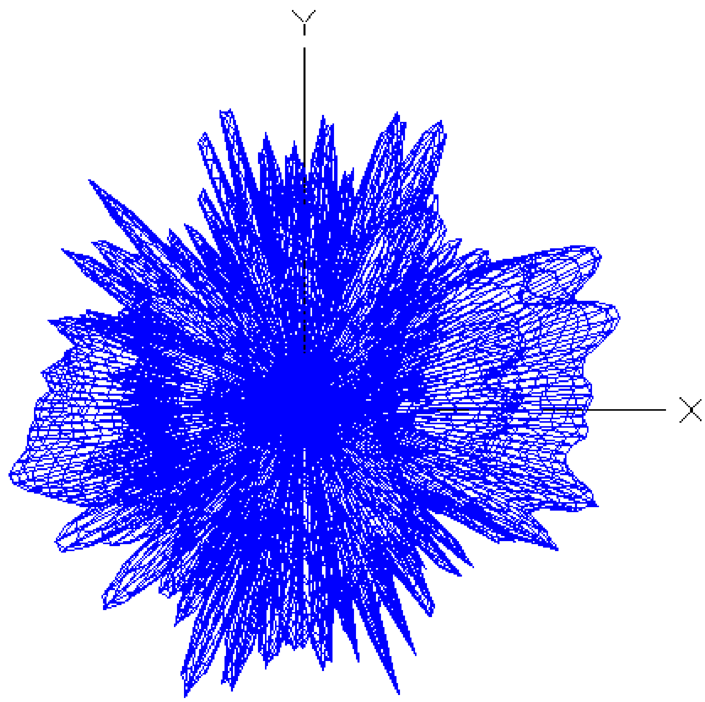

Figure 4: This bird's-eye-view of the pattern from a power-line model with only two additional legs has become impossibly complex. Making measurements at a few points around this pattern would probably not find the peak field strength. When additional loads and conductors, such as would be found in the electrical wiring in a single building, are connected to the model, the pattern would generally become even more complex and asymmetrical. (file:comp20m.ez.)

4. Near-field Considerations

4.1 § 15.31(f)(1) and (2) state that it is best to make measurements at the distances specified in the regulations, but the rules do permit measurements to be made at other distances if it is not practicable to measure at the required distance. Below 30 MHz, if measurements are made at other distances, the test engineer is permitted to either measure the fields at two points to determine the correct extrapolation factor or to use 40 dB/distance decade to estimate the field at the specified distance.

4.2 This technique may work reasonably well for very small radiators, but for physically large systems, all such points are in the reactive or radiating near-field region of the radiating conductors. In the near-field region of large, complex radiators, the fields vary in very complex ways and a "proper extrapolation" factor simply does not exist. This can be seen in the preceding antenna patterns and the following graphs. For a large radiator, 40 dB/decade is exactly backwards – in the near field region, electric or magnetic field strength can actually increase with distance, although if the peaks can be found (an uncertain assumption at best), they generally do decrease with distance, although not always in a linear or easily predicted fashion.

4.3 The following graphs and discussion are based on the power-line model shown in Figure 1.

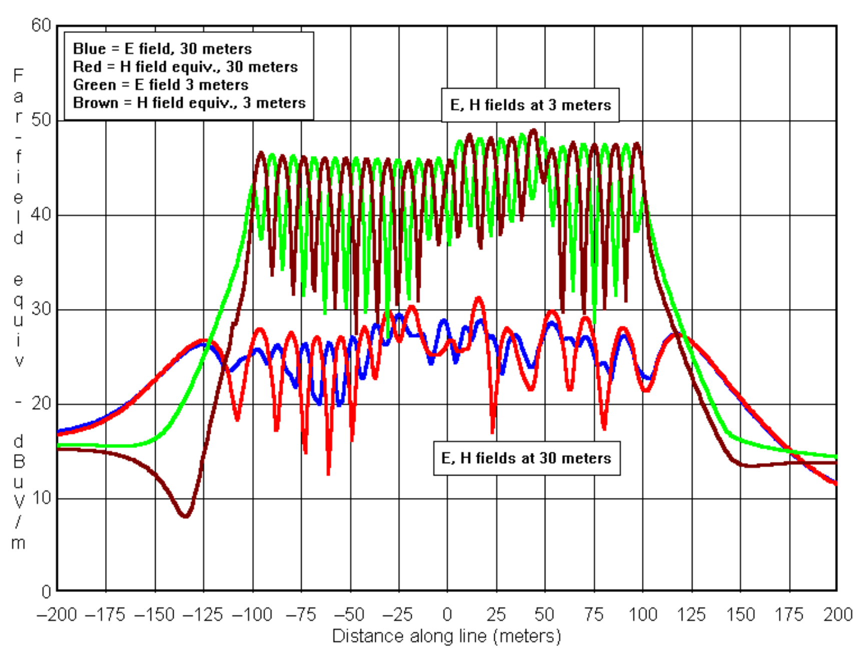

Figure 5: This graph shows the calculated electric and magnetic fields on 14 MHz at points 3 and 30 meters from the line, parallel to the line at a height of 10 meters. (files: dip14e30.ez, dip14h30.ez, dip14e3.ez, dip14h3.ez, dip14-1.txt, dip14-1.tif)

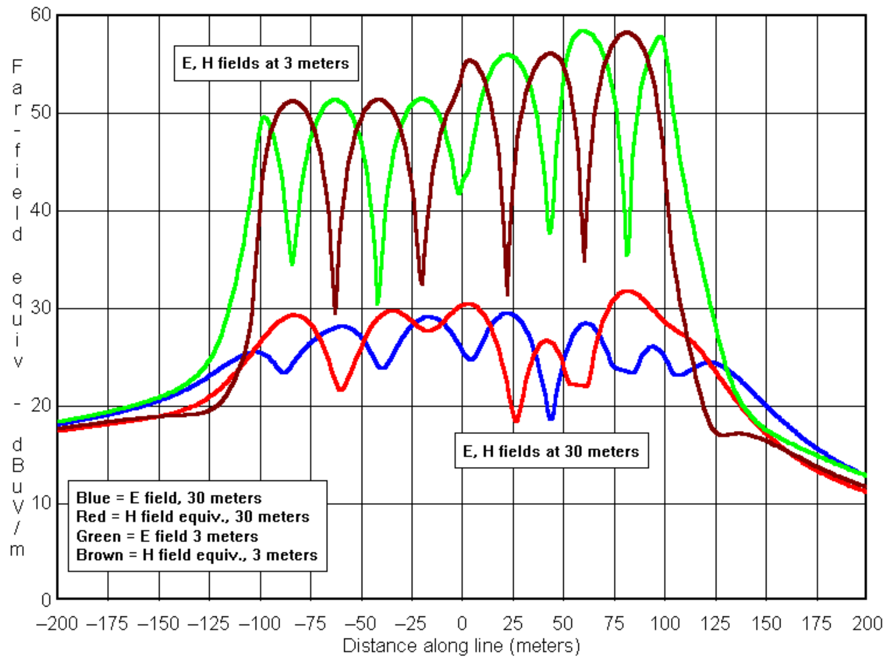

Figure 6: This graph shows the calculated electric and magnetic fields on 3.5 MHz at points 3 and 30 meters from the line, parallel to the line, at a height of 10 meters. (files: dip3r5e30.ez, dip3r5h30.ez, dip3r5e3.ez, dip3r5h3.ez, dip3-1.txt, dip3-1.tif)

4.4 In environments near complex radiating conductors, it would be very difficult to find the peaks associated with these varying fields. There is no "actual extrapolation factor" associated with the way the field strength pattern varies wildly around this power-line radiator. Certainly, it is not likely that even an approximation of the relationship between the peak field at 3 meters and the peak field at 30 meters could be established with just the two measurements stipulated in Part 15. A careful inspection of the graphs shows that the peaks and valleys are not always perpendicular with each other, with the differences in the valleys resulting in changes of ten dB or more by moving horizontally a few meters.

4.5 These data also show that a distance extrapolation factor of 40 dB/decade would not be appropriate for large radiators such as overhead power lines. ARRL has run a number of EZNEC models and in no case has it seen anything approaching 40 dB/distance decade for large radiators. The data in this report are representative of the results found over years of antenna modeling of large structures. In using the FCC-recommended method of extrapolating the electric field from the strongest magnetic field, on 14 MHz, the "actual" extrapolation factor is 15 dB between 3 and 30 meters. On 3.5 MHz, the factor is 24 dB. At other distances, 10 meters vs 30 meters, perhaps, even this simple model shows a still-different extrapolation factor.

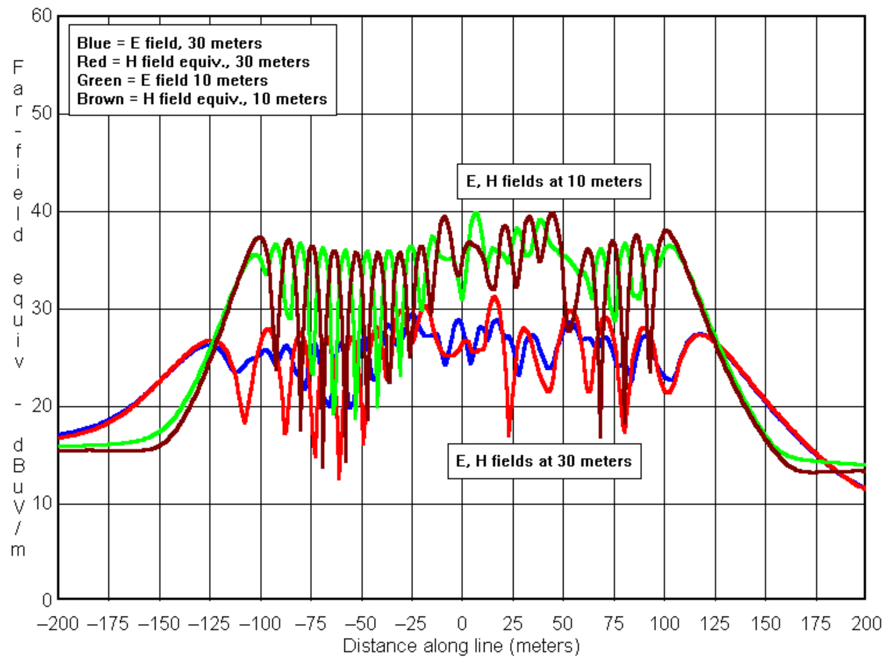

Figure 7: When the fields at 30 meters are compared to the fields at 10 meters on 14 MHz, the whole extrapolation premise falls apart altogether! (files: dip14e30.ez, dip14h30.ez, dip14e10.ez, dip14h10.ez, dip14-2.txt, dip14-2.tif)

4.6 This can be seen dramatically in Figure 7. Note that in at least one case, the magnetic field at 30 meters is slightly higher than it is at 10 meters distance. Not only does the 40 dB/decade rule fail badly in this case, the whole concept of “extrapolation factor” simply does not exist in near-field regions around large radiators.

5. Field vs Patterns

5.1 The rules permit specified maximum field strength at specific distances from the radiator. As can be seen from Figures 2 and 3, much of the energy radiated by power lines is radiated upward. To accurately know the field strength created by a particular radiator, it may be necessary to measure the fields above the radiator. It is unlikely that anyone testing a power line will place a test antenna at a height of 30 meters above the lines. It would be quite convenient for inexperienced test engineers to make measurements near ground level, using the short tripods and masts that come with most EMC antennas. Figure 8 shows the way that the calculate electric fields vary with height above ground for 3 points along the line, at a horizontal distance of 10 meters from the line. This model was run on 14 MHz.

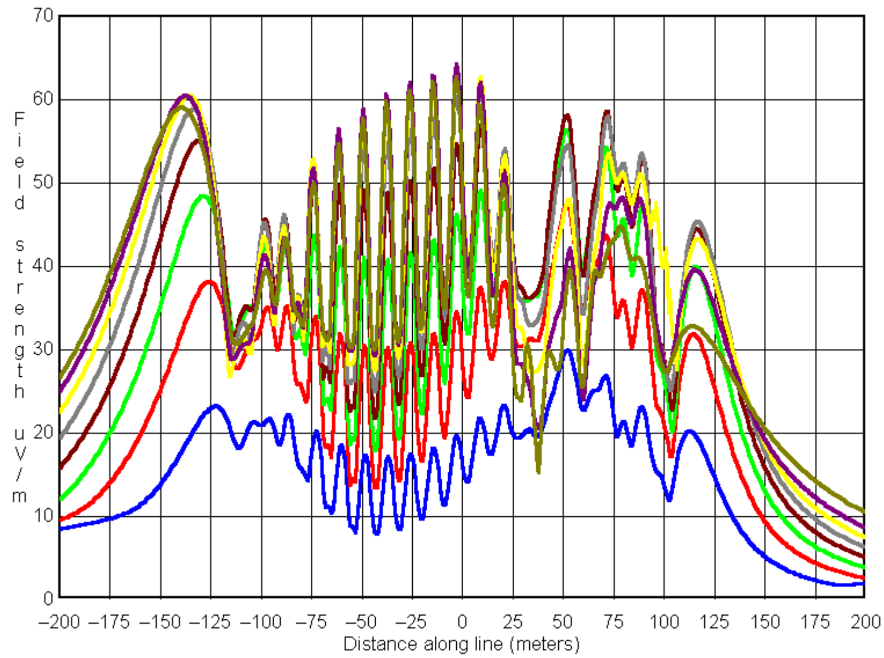

Figure 8. The calculated results obtained can increase or decrease depending on the height above ground of the simulated measurement point. These 14-MHz data were calculated at 5 through 40 meters above ground, along the length of the line, at an absolute distance of 30 meters from the line radially. The blue line, calculated at the lowest height, is the lowest electric field strength shown on the graph. The field strength was normalized to 30 uV/m for this line, and the other field strengths were scaled to the 5-meter height level. The maximum field strength increases with height for this model. The power-line model extends from –100 to +100 meters along the X axis. This calculation extends past the line by another 100 meters in each direction. Note that not only is the field strength higher above the line than at lower heights, at some heights, the point of maximum field strength is some 35 meters past the end of the line. At other heights, the maximum field strength at one height would be near a minimum field strength if measured at a lower height along the same Y axis. (files: dip14e30.ez , all.txt, all.tif)

5.2 As seen in the graph in Figure 8, the maximum radiated fields are often found above the power lines. If the fields were measured below the lines and thus underestimated the actual radiated emissions, the resultant radiated emissions would have significant implications for any aeronautical operation (amateur, commercial or military) and for any receive antennas higher than the lines. This would also increase the level of aggregate signals propagated by skywave as compared to the level if those same signals were radiated at the present Part 15 limits.

6. Conclusions

6.1 The model used by ARRL is much less complex than real world installations, yet even in this simplified model, it would be hard to predict just where to make measurements to obtain the actual maximum value of the electric field at 30 meters distance. These peaks occur at only specific places and it is likely that practical measurements would be made at points that will underestimate this peak, sometimes by tens of dB. Determination of an extrapolation factor for distance is not possible, yet if the extrapolation factor of 40 dB/decade were used, in one of these models, the error would be as much as an additional 25 dB underestimation of the electric field at 30 meters. Making measurements at the height of the line or lower adds several more dB of uncertainty. If the true peak is not found, this adds several more dB. If all of these factors add up in the wrong direction, the total error in the measurement could be greater than 40 dB.

6.2 The only way these measurements can be made accurately in-situ is to make measurements at the specified distances at closely spaced intervals above, below and to the sides of the installation. Electrical distribution systems often vary considerably in their physical characteristics at different points in the system, with significantly different potential to radiate. Antenna modeling of simple changes in this structure shows significant differences in the antenna gain of the radiating conductors, indicating a corresponding difference in the radiate near electric and magnetic fields. If measurements are to be used to demonstrate compliance, they must be made at more than "3 typical" parts of a system because with all of the variables, there are a lot more than 3 possible permutations of the factors involved and no such "typical" configuration can be representative of the wide variation in the emissions potential from such a large and diversely configured system.

Appendix A: Sample NEC files for the models used in this analysis.

DIP3R5.NEC

```
CM Differential 1 phase, 3.5 MHz
CE
GW 1,11,120.516,32.9771,10.,79.4021,33.,10.,.00635
GW 2,11,120.516,-22.34,30.,79.4021,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,3.,10.,0.,3.,10.,.00635
GW 6,95,0.,3.,10.,100.,3.,10.,.00635
GW 7,3,100.,0.,10.,100.,3.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,3.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,2,6,6,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NE 0,401,1,1,-200.,30.,10.,1.,0.,0.
EN
```

DIP14.NEC

```
CM Differential, 1 phase, 14 MHz
CE
GW 1,11,105.,31.,10.,95.,31.,10.,.00635
GW 2,11,105.,-22.34,30.,95.,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 4,1,6,6,50.,0.
LD 4,2,6,6,50.,0.
LD 4,7,2,2,50.,0.
LD 4,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,200,1,1,1.,-10.,10.,1.,0.,0.
EN
```

COMP20M.NEC

```
CM Complex power distribution
CE
GW 1,95,-100.,0.,10.,0.,0.,10.,.00635
GW 2,95,0.,0.,10.,101.,0.,10.,.00635
GW 3,95,-101.,1.,10.,0.,1.,10.,.00635
GW 4,95,0.,1.,10.,100.,1.,10.,.00635
GW 5,95,-100.,0.,10.,-100.,-100.,11.,.00635
GW 6,95,-101.,1.,10.,-101.,-100.,11.,.00635
GW 7,3,-100.,-100.,11.,-101.,-100.,11.,.00635
GW 8,95,101.,0.,10.,101.,100.,11.,.00635
GW 9,95,100.,1.,10.,100.,100.,11.,.00635
GW 10,3,101.,100.,11.,100.,100.,11.,.00635
GW 11,31,0.,0.,10.,0.,0.,.05,.00635
GW 12,11,0.,0.,.05,0.,10.,.05,.00635
GW 13,11,0.,0.,.05,-10.,0.,.05,.00635
GW 14,11,0.,0.,.05,0.,-10.,.05,.00635
GW 15,11,0.,0.,.05,10.,0.,.05,.00635
GE 1
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
LD 5,14,0,0,5.7471E+7,1.
LD 5,15,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,4,48,0,1.414214,0.
RP 0,91,90,1000,90.,0.,-2.,2.,0.
NH 0,401,1,1,-200.,-30.,10.,1.,0.,0.
EN
```

DIP14E30.NEC

```
CM Differential, 1 phase, 14 MHz
GW 1,11,105.,33.,10.,95.,33.,10.,.00635
GW 2,11,105.,-22.34,30.,95.,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,1.51E-06,.05,.00635
GW 12,11,0.,0.,.05,-4.649E-6,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,-3.02E-06,.05,.00635
GE 1
LD  4 ,1,6,6,50.,0.
LD  4 ,2,6,6,50.,0.
LD  4 ,7,2,2,50.,0.
LD  4 ,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,46,181,1001,0.,0.,2.,2.,0.
NE 0,401,1,1,-200.,-30.,10.,1.,0.,0.
EN
```

DIP14H30.NEC

```
CM Differential, 1 phase, 14 MHz
CE
GW 1,11,105.,33.,10.,95.,33.,10.,.00635
GW 2,11,105.,-22.34,30.,95.,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,1.51E-06,.05,.00635
GW 12,11,0.,0.,.05,-4.649E-6,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,-3.02E-06,.05,.00635
GE 1
LD  4 ,1,6,6,50.,0.
LD  4 ,2,6,6,50.,0.
LD  4 ,7,2,2,50.,0.
LD  4 ,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,46,181,1001,0.,0.,2.,2.,0.
NH 0,401,1,1,-200.,-30.,10.,1.,0.,0.
EN
```

DIP14E10.NEC

```
CM Differential, 1 phase, 14 MHz
CE
GW 1,11,105.,33.,10.,95.,33.,10.,.00635
GW 2,11,105.,-22.34,30.,95.,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,1.51E-06,.05,.00635
GW 12,11,0.,0.,.05,-4.649E-6,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,-3.02E-06,.05,.00635
GE 1
LD  4 ,1,6,6,50.,0.
LD  4 ,2,6,6,50.,0.
LD  4 ,7,2,2,50.,0.
LD  4 ,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,46,181,1001,0.,0.,2.,2.,0.
NE 0,401,1,1,-200.,-10.,10.,1.,0.,0.
EN
```

DIP14H10.NEC

```
CM Differential, 1 phase, 14 MHz
CE
GW 1,11,105.,33.,10.,95.,33.,10.,.00635
GW 2,11,105.,-22.34,30.,95.,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,1.51E-06,.05,.00635
GW 12,11,0.,0.,.05,-4.649E-6,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,-3.02E-06,.05,.00635
GE 1
LD  4 ,1,6,6,50.,0.
LD  4 ,2,6,6,50.,0.
LD  4 ,7,2,2,50.,0.
LD  4 ,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,46,181,1001,0.,0.,2.,2.,0.
NH 0,401,1,1,-200.,-10.,10.,1.,0.,0.
EN
```

DIP14E3.NEC

```
CM Differential, 1 phase, 14 MHz
CE
GW 1,11,105.,33.,10.,95.,33.,10.,.00635
GW 2,11,105.,-22.34,30.,95.,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,1.51E-06,.05,.00635
GW 12,11,0.,0.,.05,-4.649E-6,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,-3.02E-06,.05,.00635
GE 1
LD  4 ,1,6,6,50.,0.
LD  4 ,2,6,6,50.,0.
LD  4 ,7,2,2,50.,0.
LD  4 ,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,46,181,1001,0.,0.,2.,2.,0.
NE 0,401,1,1,-200.,-3.,10.,1.,0.,0.
EN
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DIP14H3.NEC

```
CM Differential, 1 phase, 14 MHz
CE
GW 1,11,105.,33.,10.,95.,33.,10.,.00635
GW 2,11,105.,-22.34,30.,95.,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,1.51E-06,.05,.00635
GW 12,11,0.,0.,.05,-4.649E-6,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,-3.02E-06,.05,.00635
GE 1
LD  4 ,1,6,6,50.,0.
LD  4 ,2,6,6,50.,0.
LD  4 ,7,2,2,50.,0.
LD  4 ,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,14.
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,46,181,1001,0.,0.,2.,2.,0.
NH 0,401,1,1,-200.,-3.,10.,1.,0.,0.
EN
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DIP3R5E30.NEC

```
CM Differential, 1 phase, 3.5 MHz
CE
GW 1,11,120.5166,32.97718,10.,79.40218,33.,10.,.00635
GW 2,11,120.5166,-22.34,30.,79.40218,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,1.51E-06,.05,.00635
GW 12,11,0.,0.,.05,-4.649E-6,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,-3.02E-06,.05,.00635
GE 1
LD  4 ,1,6,6,50.,0.
LD  4 ,2,6,6,50.,0.
LD  4 ,7,2,2,50.,0.
LD  4 ,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,46,181,1001,0.,0.,2.,2.,0.
NE 0,401,1,1,-200.,-30.,10.,1.,0.,0.
EN
```

DIP3R5H30.NEC

```
CM Differential, 1 phase, 3.5 MHz
CE
GW 1,11,120.5166,32.97718,10.,79.40218,33.,10.,.00635
GW 2,11,120.5166,-22.34,30.,79.40218,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,1.51E-06,.05,.00635
GW 12,11,0.,0.,.05,-4.649E-6,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,-3.02E-06,.05,.00635
GE 1
LD  4 ,1,6,6,50.,0.
LD  4 ,2,6,6,50.,0.
LD  4 ,7,2,2,50.,0.
LD  4 ,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,46,181,1001,0.,0.,2.,2.,0.
NH 0,401,1,1,-200.,-30.,10.,1.,0.,0.
EN
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DIP3R5E10.NEC

```
CM Differential, 1 phase, 3.5 MHz
CE
GW 1,11,120.5166,32.97718,10.,79.40218,33.,10.,.00635
GW 2,11,120.5166,-22.34,30.,79.40218,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,1.51E-06,.05,.00635
GW 12,11,0.,0.,.05,-4.649E-6,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,-3.02E-06,.05,.00635
GE 1
LD  4 ,1,6,6,50.,0.
LD  4 ,2,6,6,50.,0.
LD  4 ,7,2,2,50.,0.
LD  4 ,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,46,181,1001,0.,0.,2.,2.,0.
NE 0,401,1,1,-200.,-10.,10.,1.,0.,0.
EN
```

DIP3R5H10.NEC

```
CM Differential, 1 phase, 3.5 MHz
CE
GW 1,11,120.5166,32.97718,10.,79.40218,33.,10.,.00635
GW 2,11,120.5166,-22.34,30.,79.40218,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,1.51E-06,.05,.00635
GW 12,11,0.,0.,.05,-4.649E-6,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,-3.02E-06,.05,.00635
GE 1
LD  4 ,1,6,6,50.,0.
LD  4 ,2,6,6,50.,0.
LD  4 ,7,2,2,50.,0.
LD  4 ,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,46,181,1001,0.,0.,2.,2.,0.
NH 0,401,1,1,-200.,-10.,10.,1.,0.,0.
EN
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DIP3R5E3.NEC

```
CM Differential, 1 phase, 3.5 MHz
CE
GW 1,11,120.5166,32.97718,10.,79.40218,33.,10.,.00635
GW 2,11,120.5166,-22.34,30.,79.40218,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,1.51E-06,.05,.00635
GW 12,11,0.,0.,.05,-4.649E-6,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,-3.02E-06,.05,.00635
GE 1
LD  4 ,1,6,6,50.,0.
LD  4 ,2,6,6,50.,0.
LD  4 ,7,2,2,50.,0.
LD  4 ,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,46,181,1001,0.,0.,2.,2.,0.
NE 0,401,1,1,-200.,-3.,10.,1.,0.,0.
EN
```

DIP3R5H3.NEC

```
CM Differential, 1 phase, 3.5 MHz
CE
GW 1,11,120.5166,32.97718,10.,79.40218,33.,10.,.00635
GW 2,11,120.5166,-22.34,30.,79.40218,-22.34,30.,.00635
GW 3,95,-100.,0.,10.,0.,0.,10.,.00635
GW 4,95,0.,0.,10.,100.,0.,10.,.00635
GW 5,95,-100.,1.,10.,0.,1.,10.,.00635
GW 6,95,0.,1.,10.,100.,1.,10.,.00635
GW 7,3,100.,0.,10.,100.,1.,10.,.00635
GW 8,3,-100.,0.,10.,-100.,1.,10.,.00635
GW 9,11,0.,0.,10.,0.,0.,.05,.00635
GW 10,11,0.,0.,.05,0.,10.,.05,.00635
GW 11,11,0.,0.,.05,-10.,1.51E-06,.05,.00635
GW 12,11,0.,0.,.05,-4.649E-6,-10.,.05,.00635
GW 13,11,0.,0.,.05,10.,-3.02E-06,.05,.00635
GE 1
LD  4 ,1,6,6,50.,0.
LD  4 ,2,6,6,50.,0.
LD  4 ,7,2,2,50.,0.
LD  4 ,8,2,2,50.,0.
LD 5,1,0,0,5.7471E+7,1.
LD 5,2,0,0,5.7471E+7,1.
LD 5,3,0,0,5.7471E+7,1.
LD 5,4,0,0,5.7471E+7,1.
LD 5,5,0,0,5.7471E+7,1.
LD 5,6,0,0,5.7471E+7,1.
LD 5,7,0,0,5.7471E+7,1.
LD 5,8,0,0,5.7471E+7,1.
LD 5,9,0,0,5.7471E+7,1.
LD 5,10,0,0,5.7471E+7,1.
LD 5,11,0,0,5.7471E+7,1.
LD 5,12,0,0,5.7471E+7,1.
LD 5,13,0,0,5.7471E+7,1.
FR 0,1,0,0,3.5
GN 2,0,0,0,13.,.005
EX 0,6,48,0,1.414214,0.
RP 0,46,181,1001,0.,0.,2.,2.,0.
NH 0,401,1,1,-200.,-3.,10.,1.,0.,0.
EN
```